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# TECHNICAL MEMORANDUM NO 9

## HUMAN HEALTH RISK ASSESSMENT
## 903 PAD, MOUND, AND EAST TRENCHES AREAS
## OPERABLE UNIT NO 2
## CHEMICALS OF CONCERN

**REVISED DRAFT**

**ROCKY FLATS PLANT**

**U S DEPARTMENT OF ENERGY**
**Rocky Flats Plant**
**Golden, Colorado**

**ENVIRONMENTAL MANAGEMENT DEPARTMENT**
**August 1993**

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# 1.0 INTRODUCTION

This Chemicals of Concern Technical Memorandum is presented as part of the Baseline Risk Assessment (BRA) for the 903 Pad, Mound Area, and East Trenches Area, otherwise known as Operable Unit 2 (OU-2), located at Rocky Flats Plant The BRA, which consists of the Human Health Risk Assessment (HHRA) and the Environmental Evaluation, will be included in the Phase II RCRA Facility Investigation/Remedial Investigation (RFI/RI) report for OU-2 The RFI/RI is being conducted pursuant to the U S Department of Energy (DOE) Environmental Restoration Program, a Compliance Agreement between DOE, the U S Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH), and the Federal Facility Agreement and Consent Order (Interagency Agreement), signed in 1991

This technical memorandum has been developed to address the selection of chemicals of concern to be evaluated in the BRA, in particular the HHRA The identification of chemicals of concern will also help focus the efforts of the environmental evaluation, environmental transport modeling, description of the nature and extent of contamination, and remedy selection

The HHRA will evaluate potential human health risks for on-site and off-site receptors under current land use and probable future land use conditions, assuming no remedial action takes place at OU-2 Chemicals of concern are organic chemicals, metals, or radionuclides that are site-related (i e , potentially related to releases of wastes or waste sources in OU-2), that exceed background range, and that could be a significant threat to human health or the environment under the exposure conditions evaluated Chemicals of concern are identified for each medium (e g , groundwater, soil, or air) through which exposure to site-related chemicals could occur Therefore, the selection of chemicals of concern supports the quantification of risk from exposure to chemicals via the exposure pathways identified in the Exposure Scenarios Technical Memorandum No 5 (DOE 1993a)

This technical memorandum focuses on selecting chemicals of concern in groundwater, subsurface soil, and surface soil, which were the media sampled during the Phase I and Phase II RFI/RI at OU-2 Exposures can also occur through the air and surface water pathways Chemicals of concern for air and surface water are chemicals of concern in soil or groundwater that could be transported by air or could migrate from soil or groundwater to surface water exposure points

This Technical Memorandum describes the process for selecting chemicals of concern detected in groundwater, subsurface soil, and surface soil at OU-2 and summarizes the chemicals of concern for each medium The general process to select potential chemicals of concern in groundwater, subsurface and surface soils is described in Section 2 0 Sections 3 0, 4 0, and 5 0 present decision criteria specific to each medium and identify the chemicals of concern selected for each medium References used in this document are provided in Section 6 0

Appendix A, "Background Comparison for Metals and Radionuclides," describes the statistical methodology used to compare OU-2 data to background data and includes tables showing the results of the statistical tests Statistical tests were used to identify metals and radionuclides whose concentrations exceed background levels and which may therefore be site-related These metals and radionuclides are retained for further evaluation as potential chemicals of concern

Appendix B, "Risk-Based Evaluation of Infrequently Detected Chemicals," presents the screening of infrequently detected compounds (<5 percent detection frequency) to identify those that merit further evaluation as potential chemicals of concern

Appendix C contains a copy of the OU-2 report titled "Domestic Water Supply Simulations," September 10, 1992 This document supports the identification of the No 1 Sandstone lithologic unit for evaluation of hypothetical on-site ingestion of groundwater

Appendix D, "Dissolved Metals and Radionuclides, No 1 Sandstone, Background Comparison," contains results of the statistical comparison to background data for dissolved metals and radionuclides in the No 1 Sandstone groundwater These results are used to support the discussion of the significance of certain total (unfiltered) metals results from this unit

# 2.0
# CHEMICALS OF CONCERN SELECTION PROCESS

The general methodology for selecting chemicals of concern for OU-2 is presented in Figure 2-1, Criteria for Identifying Chemicals of Concern The process is intended to identify chemicals in each medium that appear to be associated with waste releases or sources in OU-2 that could have adverse impacts on public health under exposure scenarios involving that medium In this way, the risk assessment is focussed on OU-2 constituents that are potential health hazards Inorganic compounds whose concentrations are within background range or that are minor constituents (e g , rarely detected and/or of low toxicity) are excluded from the risk assessment Organic compounds that would contribute negligibly or not at all to overall risk are identified but are not included in the quantitative risk assessment It is important that the chemicals of concern be carefully selected so that risk is not underestimated and so as not to distract from the dominant risks associated with the OU

This selection process was based on guidance presented in Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A (EPA 1989) The background comparison methodology was based on the Final Background Geochemical Characterization Report, Rocky Flats Plant (EG&G 1992) and on standard statistical evaluation techniques

The steps shown in Figure 2-1 and described in the following sections were applied to select chemicals of concern for all three media sampled during the remedial investigation (groundwater, subsurface soil, and surface soil) Details of the application of the process for each medium are presented in Sections 3 0 (groundwater), 4 0 (subsurface soil), and 5 0 (surface soil)

The individual steps shown in Figure 2-1 are identified below Each step is described in more detail in Subsections 2 1 through 2 5

Step 1 - Site-Specific Chemical Analysis Roster

Table 2-1 is the Site-Specific Chemical Analysis Roster (SSCAR) for the Phase II sampling program at OU-2 Analytical results for all detected compounds in the following analyte groups are included in the data set for evaluation as potential chemicals of concern for risk assessment metals (target analyte list and "other metals"), radionuclides, and organics

Step 2 - Data Evaluation

The analytical results from the OU-2 sampling program were reviewed and compiled in a database by the validation contractor Data validation was performed for some but not all of the data prior to use The database was then reviewed for its suitability for selecting chemicals of concern For example, data qualifiers were considered and quality control samples were removed from the database

Step 3 - Background Comparison (Metals and Radionuclides)

Analytical results for metals and radionuclides were compared to background levels derived from data for subsurface soils and groundwater reported in the Background Geochemical Characterization Report (EG&G 1992) and from background surface soil samples collected in the Rock Creek area Metals and radionuclides whose concentrations did not exceed background levels were eliminated from further consideration as potential chemicals of concern The following criteria were used to evaluate whether a metal or radionuclide exceeded background levels

a Analytical results for metals and radionuclides were compared to the 95 percent upper tolerance limit (95% UTL) of the background data If less than 5 percent of the results exceeded the 95% UTL, the constituent was considered to be within background range Analysis of variance (ANOVA) was used to confirm this assessment

b The OU-2 data for metals and radionuclides were statistically compared to background data using analysis of variance (ANOVA) If no statistical difference was found, the analyte was considered to be within background range

c Spatial/temporal evaluation of analytes that appeared to exceed background by one or more of the statistical tests was performed to identify analytes that are unlikely to be related to waste releases in OU-2

Step 4 - Eliminate Essential Nutrients and Anions

Constituents such as calcium, potassium, iron, and carbonate were eliminated from further consideration as chemicals of concern due to low toxicity and because they are usually not waste- related

Step 5 - Detection Frequency

All detected organic target analytes were separated into two groups based on detection frequency Compounds detected at 5 percent or greater detection frequency were evaluated further in Step 6 Contaminants detected below 5 percent frequency were evaluated in Steps 8 and 9

Step 6 - Concentration/Toxicity Screen

A concentration/toxicity screen, using maximum detected concentrations and EPA-established toxicity factors, was performed for all organic chemicals with a detection frequency equal to or greater than 5 percent, and for metals and radionuclides that exceed background levels The concentration/toxicity screen identified those compounds that are likely to contribute to 99 percent or more of the total risk These compounds are identified as chemicals of concern for evaluation in the quantitative risk assessment

EPA-established toxicity factors are not available for some of the target analytes Therefore, these analytes cannot be included in the concentration/toxicity screens, in other toxicity-based screens, or in the quantitative risk assessment OU-2 contaminants without toxicity factors were identified for each medium (surface and subsurface soil and groundwater) and are listed in each section The potential impact of these compounds on overall risk will be addressed qualitatively in the human health risk assessment

Step 7 - Chemicals of Concern

Organic compounds, metals, and radionuclides that contribute to 99 percent or more of a total risk factor, based on Step 6, were retained as chemicals of concern for quantitative evaluation in the human health risk assessment

Step 8 - Evaluation of Infrequently Detected Compounds

The maximum concentration of each organic compound detected at less than 5 percent frequency was compared to a screening-level concentration equivalent to 1000 times a health risk-based concentration (RBC) This step identifies infrequently detected compounds that could contribute significantly to risk if exposure were to occur

Step 9 - Spatial and Temporal Evaluation of Infrequently Detected but Potentially Hazardous Compounds

Infrequently detected organic compounds whose maximum concentration exceeded 1000 times the RBC were evaluated for spatial and temporal distribution of the detected values If the compounds appeared to be related to waste sources or if spatial and temporal distribution indicated that the constituent is of potential concern for current or future exposures, these chemicals were retained as "special-case" chemicals of concern

Step 10 - Special Case Chemicals of Concern

Compounds whose maximum concentration exceeded the screening values (Step 8) and with significant spatial and temporal distributions (e g, detected in association with elevated concentrations of other chemicals of concern) (Step 9), as well as certain inorganic compounds with highly localized, source-related occurrences of concentrations above background, were retained as "special case" chemicals of concern to be addressed separately in the risk assessment

Step 11 - Professional Judgment

Chemicals or radionuclides that were eliminated as chemicals of concern by the above criteria may be retained on the basis of professional judgment

## 2.1 DATA EVALUATION

Table 2-2, OU-2 Analytical Data File Summary, presents the data files used to select chemicals of concern for OU-2 For groundwater, six quarters of monitoring data (2nd quarter 1991 through 3rd quarter 1992) were used, because for these quarters at least 50 percent of the data had been validated (fewer of the earlier data were validated) For subsurface soil (borehole), data from samples collected above the high water table in 1987 (Phase I investigation) and in 1991 and 1992 (Phase II investigation) were used The 1987 Phase I borehole data were not validated Borehole samples collected below the high water table were not used to select chemicals of concern in subsurface soils to avoid the potential problem of cross-contamination from groundwater biasing the selection Surface soil data collected in 1991 and 1993 were included in the data set

Some of the chemical analytical results have not been validated Unvalidated data received from Rocky Flats Environmental Data System (RFEDS) were integrated with validated data received from Quantalex Laboratory If unvalidated and validated data for the same sample were found in the database, the unvalidated data were eliminated Data that had not yet been through the validation process were used if no validated data were available

Lithologic identifications for the groundwater monitoring data were determined, and only wells completed in the Upper Hydrostratigraphic Unit (UHSU) were included in the groundwater data set The UHSU includes the alluvium, colluvium, valley fill, and the uppermost Arapahoe Sandstone (No 1 Sandstone) The OU-2 bedrock investigation (DOE 1993b) will address any potential contamination of the Lower HSU (LHSU) Chemicals of concern for assessing human health risk from on-site groundwater ingestion were selected from analytes detected in the No 1 Sandstone (uppermost Arapahoe) This approach is based on the finding, presented in the OU-2 Water Supply Simulations document (Appendix C), that the uppermost Arapahoe sandstone is the only lithologic unit within the UHSU that could support a domestic water well (see Appendix C) Groundwater data from all units in the UHSU were used for evaluating migration of contaminants in groundwater to potential exposure points in Woman Creek and Walnut Creek

The next step in the data evaluation process was to remove quality control samples, such as blanks, spikes, and rinsates, from the database Data qualifiers for chemicals (e g , B, E, D and R) were identified and the following revisions to the database were made

- E qualified data (exceeded calibration range) were replaced with the associated D qualified data (diluted to within calibration range) The E qualifier for metal analytical results indicates that the reported value was estimated due to interference These data were used as reported

- The B qualifier assigned to an organic compound (volatile, semivolatile, pesticide, or polychlorinated biphenyl [PCB]) signifies that the compound was found in both the sample and the associated laboratory blank For validated data, if the reported sample concentration for a B qualified compound that is not a common laboratory contaminant was greater than five times the reported concentration in the blank, the analytical result was used as reported If not, the result was qualified with a U by the validation contractor and the result reported as non-detect at the reported value If the reported sample concentration for a B qualified compound that is a common laboratory contaminant (e g , acetone, methylene chloride, 2-butanone, bis(2-ethylhexyl) phthalate) was greater than ten times the reported concentration in the blank, the analytical result was used as reported If not, the result was qualified with a U by the validation contractor and the result reported as non-detect at the reported value

For non-validated data, B qualified results have been reported in the database, however, there was no connection in the database between non-validated B qualified results and the associated laboratory blanks or rinsate blanks Because the effect of blank contamination on the B qualified results could not be assessed, the non-validated B qualified results were not included in the working database for selection of chemicals of concern The removal of these unvalidated B qualified results from the working database does not adversely affect the usability of the data for selection of chemicals of concern for the following reasons

(1) Relatively few results were removed (475 results, or less than 1 percent of the total number of analytical results)

(2) About 75 percent of the results that were removed were B qualified results for the common laboratory contaminants acetone, methylene chloride, and phthalates, about 20 percent of the non-validated B qualified results were for tentatively identified compounds (TICs) in surface soil samples, and about 5 percent of the removed results were for miscellaneous volatile organics in groundwater samples that were also detected in laboratory or rinsate blanks Therefore, most of the removed results are for compounds that are not likely to be chemicals of concern in risk assessment

(3) In the validated data set, most B qualified results for common laboratory contaminants were changed to U qualified results (non-detect) during validation Therefore, it is probable that most of the other B qualified results for these compounds would also have been qualified as non-detect

The largest effect of removing the non-validated B qualified results from the database for selecting chemicals of concern is to change the frequency of detection of compounds that are common laboratory contaminants by a small percentage because the total number of results for each analyte is reduced by the number of non-validated B qualified results removed This is not considered to adversely affect the identification of site-related chemicals of concern for risk assessment

Non-validated B qualified analytical results are being replaced in the database with validated results where possible

The B qualifier for a metal result signifies that the reported concentration is greater than the instrument detection limit but less than the Contract Required Quantitation Limit (CRQL) for that analyte These data were used as reported

- R qualified data (not usable according to EPA criteria) were eliminated R qualified results represent a very small fraction of the entire data set and only appear in validated data

Data qualified with J or U were used as follows

- Analytical results were J qualified if the compound was positively identified below the quantitation limit The result was considered an estimate because of the uncertainty associated with detected concentrations at low levels Data qualified with a J were used as reported

- A U qualifier assigned to an analytical result indicates that the analyzed chemical was not detected above the sample quantitation limit The U qualifier was the primary mechanism used for evaluating detection frequency for the organic and inorganic constituents The U qualified data were used as non-detects for detection frequency determination, but one-half the reporting limit was used as the concentration in the statistical evaluations

There were numerous instances where multiple analytical results for a given sample were reported in the RFEDS database Circumstances that may have resulted in multiple results being reported and the action taken during review of the database include

- Validated and non-validated results were reported for the same sample In all cases where a validated and non-validated sample result were reported, the result from the validated record was retained in the database

- Results from multiple dilutions were reported for the same sample Multiple dilutions were typically reported for the analyses for volatile and semivolatile organics due to one or more analytes exceeding the calibration range for the initial analysis In cases where the result was flagged with an E qualifier by the laboratory, the action taken was as described above In cases where non-detects were reported for an analyte in both the initial and diluted samples, the value with the lower detection limit was retained In cases where the results were reported as detected in both the initial and diluted samples, the higher value was retained in the database

- Results from both an initial analysis and a re-analysis or re-extraction were reported for the same sample For non-validated results, the reason for the re-analysis or re-extraction were not reported (e g, calibration, surrogates, internal standard areas) and it was not possible to determine if the problem requiring the re-analysis was corrected or if the re-analysis was performed within holding times Therefore, in cases where non-detects were reported for an analyte in both the initial and re-analyzed samples, the value with the lower detection limit was retained In cases where the results were reported as detected in both the initial and re-analyzed samples, the higher value was retained in the database

- Multiple results for volatiles method 502 2 reported for the same sample, each with a DF qualifier the higher of the two DF qualified results were used in the data set for evaluating chemicals of concern

For radionuclides, negative values were considered non-detect, and values less than the laboratory reporting limit were used as positive results or non-detects in accordance with qualifiers assigned during data validation

## 2.2 BACKGROUND COMPARISON FOR INORGANIC COMPOUNDS

OU-2 sample results for metals and radionuclides in soil and groundwater were compared to background data to determine which inorganic constituents exceeded background range and, therefore, may be related to waste sources in OU-2 (Essential nutrients, such as iron, potassium, calcium, sodium, and magnesium, and anions with low toxicity, such as carbonate, bicarbonate, chloride, sulfate, nitrate, fluoride, bromide, silica, ammonium, and orthophosphate, were eliminated from consideration as potential chemicals of concern and were not included in the background comparison ) Appendix A describes the details of the approach used to compare OU-2 sample results with background concentrations The results of the statistical comparison are presented in Tables A-1 through A-16 in Appendix A

## 2.3 FREQUENCY OF DETECTION

All detected volatiles, semivolatiles, pesticides, and PCBs, as well as metals and radionuclides that exceeded background range, were evaluated for frequency of detection Compounds detected at a frequency of 5 percent or greater were considered potential chemicals of concern These compounds were included in concentration/toxicity screens to identify compounds that could contribute significantly to total risk (see Section 2 4) Compounds detected at less than 5 percent frequency (for example, in fewer than 2 of 40 samples or in fewer than 5 of 100 samples) can be eliminated from further consideration because the compound is not characteristic of site contamination and the potential for exposure is low Nevertheless, concentrations of infrequently detected organic compounds were further evaluated as described in Section 2 5 (and Steps 8, 9, and 10 of Figure 2-1) to identify those that could contribute significantly to risk if routine exposure were to occur

## 2.4 CONCENTRATION/TOXICITY SCREEN

Concentration/toxicity screens were performed for each chemical detected at 5 percent frequency or greater in each medium of concern (groundwater, subsurface soils, and surface soils) The purpose of applying the screen is to focus the risk assessment on the chief contributors to potential risk To perform the screen, each chemical in a medium (such as groundwater) is scored according to its maximum concentration and toxicity to obtain a risk factor The risk factor for noncarcinogenic effects is the concentration divided by the EPA Reference Dose (RfD) for that chemical The risk factor for carcinogenic effects (and for radionuclides) is the concentration (activity) multiplied by the EPA cancer slope factor for that chemical The chemical-specific risk factors are summed to calculate total risk factors for the noncarcinogenic, carcinogenic, and radioactive chemicals of potential concern in each medium The ratio of the risk factor for each chemical to the total risk factor approximates the relative risk for each chemical in the medium Separate concentration/toxicity screens are performed for carcinogenic and noncarcinogenic effects of organic compounds and metals and for carcinogenic effects of radionuclides

EPA-recommended toxicity factors (RfDs and cancer slope factors) were used in the concentration/toxicity screens (Step 6, Figure 2-1) and in the calculation of risk-based concentrations (Step 9, Figure 2-1) Slope factors and RfDs were determined from IRIS (EPA 1993), HEAST (EPA 1992a including later supplements) and HEAST (EPA 1991) and are listed in Tables 2-3 and 2-4 Chemicals of potential concern that do not have EPA-established toxicity factors cannot be evaluated quantitatively in the concentration/toxicity screens or in the risk assessment These are listed in each section for each medium However, their potential contribution to risk will be evaluated qualitatively in the risk assessment

Chemicals with very low risk factor ratios compared to other chemicals in the medium were eliminated from further consideration because of their very low potential to contribute to overall risk In this step of the selection process, all chemicals that comprise approximately 99 percent of the total risk factor were considered chemicals of concern for evaluation in the quantitative risk assessment This approach greatly reduces the number of chemicals to be carried through a risk assessment However, the approach is conservative (health protective) because it retains some chemicals that contribute as little as 1 percent of the total potential risk In most cases, only a few chemicals contribute the majority of risk from each medium

## 2.5 EVALUATION OF INFREQUENTLY DETECTED COMPOUNDS

Chemicals detected infrequently (in less than 5 percent of all samples in the medium) can usually be eliminated from consideration as chemicals of concern because they are not characteristic of site contamination and the potential for exposure is low However, these compounds were further screened so as not to neglect an infrequently detected compound that could contribute significantly to risk if routine exposure were to occur In this analysis, maximum measured concentrations were compared to screening levels equivalent to 1000 x RBCs This analysis, summarized below, is presented in detail in Appendix B

For screening purposes, RBCs were defined as chemical concentrations associated with an excess cancer risk of $10^{-6}$ (1 in 1 million) or a hazard index for noncarcinogenic effects of 1 0, assuming residential exposures Any infrequently detected chemical measured at a concentration greater than 1000 times the respective RBC was identified as representing a potential health threat to exposed receptor populations and was included in the list of OU-2 "special case" chemicals of concern for evaluation in the risk assessment

RBCs were calculated assuming a residential exposure scenario, using conservative exposure assumptions, and using standard toxicity values (RfDs and SFs) published by EPA RBCs for chemicals in surface and subsurface soils were calculated assuming multiple pathway exposure (ingestion, dermal contact, and inhalation of particulates) RBCs for chemicals in groundwater were calculated based on ingestion only, since this was assumed to be the chief groundwater exposure route The exposure parameters used to calculate RBCs are presented in Appendix B They are the same as those presented in the Exposure Scenarios Technical Memorandum No 5 (DOE 1993a) Toxicity values used to calculate RBCs are listed in Table 2-3

**TABLE 2-1**
**ROCKY FLATS PLANT OU-2**
**SITE-SPECIFIC CHEMICAL ANALYSIS ROSTER**
**PHASE II OU-2 SAMPLING PARAMETERS**

**TOTAL METALS**
**Target Analyte List**
Soil
Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Vanadium
Zinc

**OTHER METALS**
Soil
Molybdenum
Strontium
Cesium
Lithium
Tin

**OTHER INORGANICS**
Soil
pH
Sulfide
Nitrate-Nitrite (as N)
Percent Solids
Cyanide
Moisture Content
Orthophosphate
Bromide
Ammonium
Silica (as Si and SiO2)

**INDICATORS**
Soil
Dissolved Organic Carbon
Total Organic Carbon

**OTHER PARAMETERS**
Total Petroleum Hydrocarbons

**METALS**
**Target Analyte List**
Groundwater
(Total and Dissolved Metals)
Aluminum
Antimony
Arsenic
Barium
Beryllium
Cadmium
Calcium
Chromium
Cobalt
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Nickel
Potassium
Selenium
Silver
Sodium
Thallium
Vanadium
Zinc

**OTHER METALS**
Groundwater
Molybdenum
Strontium
Cesium
Lithium
Tin

**FIELD PARAMETERS**
Groundwater
pH
Specific Conductance
Temperature
Dissolved Oxygen

**INDICATORS**
Groudwater
Total Organic Carbon
Dissolved Organic Carbon
pH

**ANIONS**
Groundwater
Carbonate
Bicarbonate
Chloride
Sulfate
Nitrate (as N)
Cyanide
Fluoride
Bromide
Silica (as Si and SiO2)
Ammonium
Orthophosphate

**OTHER PARAMETERS**
Total Petroleum Hydrocarbons

**TABLE 2-1**
**(Continued)**

| | | |
|---|---|---|
| **ORGANICS· VOLATILES** | **ORGANICS· PESTICIDES/PCBs** | **TOTAL RADIONUCLIDES** |
| **Target Compound List** | **Target Compound List** | Soil |
| Soil and Groundwater | Soil and Groundwater | Gross Alpha |
| Chloromethane | alpha-BHC | Gross Beta |
| Bromomethane | beta-BHC | Uranium-233, 234, 235, and 238 |
| Vinyl Chloride | delta-BHC | Americium-241 |
| Chloroethane | gamma-BHC (Lindane) | Plutonium-239 and 240 |
| Methylene Chloride | Heptachlor | Tritium |
| Acetone | Aldrin | Strontium-89,90 |
| Carbon Disulfide | Heptchlor Epoxide | Cesium-137 |
| 1,1-Dichloroethene | Endosulfan I | Radium-226, 228 |
| 1,1-Dichloroethane | Dieldrin | |
| Total 1,2-Dichloroethene | 4,4'-DDE | **DISSOLVED RADIONUCLIDES** |
| Chloroform | Endrin | Groundwater |
| 1,2-Dichloroethane | Endosulfan II | Gross Alpha |
| 2-Butanone | 4,4'-DDD | Gross Beta |
| 1,1,1-Trichloroethane | Endosulfan Sulfate | Uranium-233, 234, 235, and 238 |
| Carbon Tetrachloride | 4,4'-DDT | Tritium |
| Vinyl Acetate | Endrin Ketone | Strontium-89, 90 |
| Bromodichloromethane | Methoxychlor | Cesium-137 |
| 1,1,2,2-Tetrachloroethane | alpha-Chlordane | Radium-226 and 228 |
| 1,2-Dichloropropane | gamma-Chlordane | Tritium |
| Trans-1,3-Dichloropropene | Toxaphene | |
| Trichloroethene | Aroclor-1016 | **TOTAL RADIONUCLIDES** |
| Dibromochloromethane | Aroclor-1221 | Groundwater |
| 1,1,2-Trichloroethane | Aroclor-1232 | Plutonium-239 and 240 |
| Benzene | Aroclor-1242 | Americium-241 |
| cis-1,3-Dichloropropene | Aroclor-1248 | Tritium |
| Bromoform | Aroclor-1254 | |
| 2-Hexanone | Aroclor-1260 | |
| 4-Methyl-2-pentanone | | |
| Tetrachloroethene | **SURFACE SOIL PARAMETERS** | |
| Toluene | Total Organic Carbon | |
| Chlorobenzene | Carbonate | |
| Ethyl Benzene | pH | |
| Styrene | Specific Conductance | |
| Total Xylenes | Plutonium-239 and 240 | |
| | Americium-241 | |

## TABLE 2-1
## (Concluded)

| ORGANICS: SEMI-VOLATILES | | |
|---|---|---|
| **Target Compound List** | | |
| Soil and Groundwater | | |
| Phenol | Hexachlorobutadiene | N-nitrosodiphenylamine |
| bis(2-Chloroethyl)ether | 4-Chloro-3-methylphenol(para-chloro- | 4-Bromophenyl Phenyl Ether |
| 2-Chlorophenol | 2-Methylnapthalene | Hexachlorobenzene |
| 1,3-Dichlorobenzene | Hexachlorocylopentadiene | Pentachlorophenol |
| 1,4-Dichlorobenzene | 2,4,6-Trichlorophenol | Phenanthrene |
| Benzyl Alcohol | 2,4,5-Trichlorophenol | Anthracene |
| 1,2-Dichlorobenzene | 2-Chloronaphthalene | Di-n-butylphthalate |
| 2-Methylphenol | 2-Nitroaniline | Fluoranthene |
| bis(2-Chloroisopropyl)ether | Dimethylphthalate | Pyrene |
| 4-Methylphenol | Acenaphthlene | Butyl Benzylphthalate |
| N-Nitroso-Dipropylamine | 3-Nitroaniline | 3,3'-Dichlorobenzidine |
| Hexachloroethane | Acenaphthene | Benzo(a)anthracene |
| Nitrobenzene | 2,4-Dinitrophenol | bis(2-ethylhexyl)phthalate |
| Isophorone | 4-Nitrophenol | Chrysene |
| 2-Nitrophenol | Dibenzofuran | Di-n-octyl Phthalate |
| 2,4-Dimethylphenol | 2,4-Dinitrotoluene | Benzo(b)fluoranthene |
| Benzoic Acid | 2,6-Dinitrotoluene | Benzo(k)fluoranthene |
| bis(2-Chloroethoxy)methane | Diethylphthalate | Benzo(a)pyrene |
| 2,4-Dichlorophenol | 4-Chlorophenyl Phenyl Ether | Indeno(1,2,3-cd)pyrene |
| 1,2,4-Trichlorobenzene | Fluorene | Dibenz(a,h)anthracene |
| Naphthalene | 4-Nitroaniline | Benzo(g,h,i)perylene |
| 4-Chloroaniline | 4 6-Dinitro-2-methylphenol | |

**TABLE 2-2**
**ROCKY FLATS PLANT OU-2**
**ANALYTICAL DATA FILE SUMMARY**

| Data File | Data Description. Borehole | | Collected By | Data Used for Chemicals of Concern |
|---|---|---|---|---|
| BH_IN87A.XLS | Inorganics 1987 (pH, solids, cyanide, etc.) | | Weston | All subsurface soil data from above high water table |
| BH_M87AN.XLS | Metals 1987 | | Weston | |
| BH_M91AN.XLS | Metals 1991 1992 | | W-C | |
| BH_P87A.XLS | Pesticides 1987 | | Weston | |
| BH_P91AN.XLS | Pesticides 1991-1992 | | W-C | |
| BH_R87AN.XLS | Radionuclides 1987 | | Weston | |
| BH_R91AN.XLS | Radionuclides 1991 1992 | | W-C | |
| BH_S87A.XLS | Semi-volatiles 1987 | | Weston | |
| BH_S91AN.XLS | Semi-volatiles 1991 1992 | | W-C | |
| BH_V87A.XLS | Volatile Organics 1987 | | Weston | |
| BH_V91AN.XLS | Volatile Organics 1991-1992 | | W-C | |
| BH_W91AN.XLS | Inorganics 1991 1992 (pH, solids, cyanide, etc.) | | W-C | |
| **Data File** | **Data Description. Groundwater** | | **Collected By** | **Data Used for Chemicals of Concern** |
| GW_P192N.XLS | Pesticides | 1st and 2nd Quarters 1992 | Site-Wide Program (IT) | 1st and 2nd Quarter 1992 |
| GWU_P91.XLS | Pesticides | All Quarters 1991 | Site-Wide Program (IT) | 2nd through 4th Quarter 1991 |
| GW_R192D.XLS | Dissolved Radionuclides | 1st and 2nd Quarters 1992 | Site Wide Program (IT) | 1st and 2nd Quarter 1992 |
| GW_R192T.XLS | Total Radionuclides | 1st and 2nd Quarters 1992 | Site Wide Program (IT) | 1st and 2nd Quarter 1992 |
| GW_R792D.XLS | Dissolved Radionuclides | 3rd and 4th Quarters 1992 | Site Wide Program (IT) | 3rd Quarter 1992 |
| GW_R792T.XLS | Total Radionuclides | 3rd and 4th Quarters 1992 | Site Wide Program (IT) | 3rd Quarter 1992 |
| GW_R90D.XLS | Dissolved Radionuclides | All Quarters 1990 | Site Wide Program (IT) | Not Used |
| GW_R90T.XLS | Total Radionuclides | All Quarters 1990 | Site Wide Program (IT) | Not Used |
| GW_R91D.XLS | Dissolved Radionuclides | All Quarters 1991 | Site Wide Program (IT) | 2nd through 4th Quarter 1991 |
| GW_R91T.XLS | Total Radionuclides | All Quarters 1991 | Site Wide Program (IT) | 2nd through 4th Quarter 1991 |
| GW_S192N.XLS | Semi Volatiles | 1st and 2nd Quarters 1992 | Site Wide Program (IT) | 1st and 2nd Quarter 1992 |
| GWU_S91.XLS | Semi Volatiles | 4th Quarter 1991 | Site Wide Program (IT) | 4th Quarter 1991 |
| GW_V192N.XLS | Volatiles | 1st and 2nd Quarters 1992 | Site Wide Program (IT) | 1st and 2nd Quarter 1992 |
| GW_V792N.XLS | Volatiles | 3rd and 4th Quarters 1992 | Site Wide Program (IT) | 3rd Quarter 1992 |
| GWU_V90.XLS | Volatiles | All Quarters 1990 | Site Wide Program (IT) | Not Used |
| GWU_V91.XLS | Volatiles | All Quarters 1991 | Site Wide Program (IT) | 2nd through 4th Quarter 1991 |
| GW_W192N.XLS | Water Quality Parameters | 1st and 2nd Quarters 1992 | Site Wide Program (IT) | Not Used |
| GW_W792N.XLS | Water Quality Parameters | 3rd and 4th Quarters 1992 | Site Wide Program (IT) | Not Used |
| GWU_W90.XLS | Water Quality Parameters | All Quarters 1990 | Site-Wide Program (IT) | Not Used |
| GWU_W91.XLS | Water Quality Parameters | All Quarters 1991 | Site Wide Program (IT) | Not Used |
| CHEMS4.XLS | Metals | 1st Quarter 1990- 4th Quarter 1992 | Site Wide Program (IT) | 2nd Qtr 1991 3rd Qtr 1992 |
| **Data File** | **Data Description. Surficial Soil** | | **Collected By** | **Data Used for Chemicals of Concern** |
| SS93FLT2.XLS | 1993 data not including background (met, rads, sv pest) | | W-C | All |
| SS_PT.XLS | 1991 data (rads) | | Stoller/W-C | All |

# TABLE 2-3
# ROCKY FLATS OU-2
# TOXICITY FACTORS FOR
# ORGANIC COMPOUNDS AND METALS

| Analyte | Oral Slope Factor 1/(mg/kg/day) | Oral RfD (mg/kg/day) | Inhalation Slope Factor 1/(mg/kg/day) | Inhalation RfD (mg/kg/day) | EPA Cancer Weight Evidence |
|---|---|---|---|---|---|
| 1,1,1,2-tetrachloroethane | 2.6E-02 (1) | 3 00E-02 (1) | 2 60E-02 (1) | - | C |
| 1,1,1-trichloroethane | - | 9 00E-02 (2) | - | 3 00E-01 (2) | - |
| 1,1,2,2-tetrachloroethane | 2 0E-01 (1) | - | 2 00E-01 (1) | - | C |
| 1,1,2-trichloroethane | 5 7E-02 (1) | 4 00E-03 (1) | 5 70E-02 (1) | - | C |
| 1,1-dichloroethane | - | 1 00E-01 (3) | - | 1 40E-01 (2) | C |
| 1,1-dichloroethene | 6 0E-01 (1) | 9 00E-03 (1) | 1 75E-01 (1) | - | C |
| 1,2,3-trichloropropane | - | 6 00E-03 (1) | - | - | - |
| 1,2,4-trichlorobenzene | - | 1 00E-02 (1) | - | 3 00E-03 (2) | - |
| 1,2-dibromo-3-chloropropane | 1 4E+00 (2) | - | 2 40E-03 (2) | 5 00E-05 (1) | B2 |
| 1,2-dibromoethane | 8 5E+01 (1) | - | 7 60E-01 (2) | - | B2 |
| 1,2-dichlorobenzene | - | 9 00E-02 (1) | - | 4 00E-02 (2) | - |
| 1,2-dichloroethane | 9 1E-02 (1) | - | 9 10E-02 (1) | - | B2 |
| 1,2-dichloroethene | - | 9 00E-03 (2) | - | - | - |
| 1,2-dichloropropane | - | - | - | 1 00E-03 (1) | - |
| 1,2-dimethylbenzene (o-xylene) | - | 2 00E+0 (1) | - | - | - |
| 1,3-dimethylbenzene (m-xylene) | - | 2 00E+0 (1) | - | - | - |
| 1,4-dichlorobenzene | 2 40E-02 (2) | - | - | 2 00E-1 (2) | C |
| 2-butanone | - | 6 0E-01 (1) | - | 3 0E-01 (1) | - |
| 4,4'-DDT | 3 40E-01 (1) | 5 00E-04 (1) | 3 40E-01 (1) | - | B2 |
| 4-methyl-2-pentanone | - | 5 00E-02 (2) | - | 2 00E-02 (2) | - |
| acenapthene | - | 6 00E-02 (1) | - | - | - |
| acetone | - | 1 00E-01 (1) | - | - | - |
| anthracene | - | 3 00E-01 (1) | - | - | - |
| antimony | - | 4 00E-04 (1) | - | - | - |
| Aroclor-1254 | 7 70E+00 (1) | - | - | - | B2 |
| arsenic | 1 75E+00 (1) | 3 00E-04 (1) | 1 50E+01 (1) | - | A |
| barium | - | 7 00E-02 (1) | - | 1 40E-04 (2) | - |
| benzene | 2 90E-02 (1) | - | 2 90E-02 (2) | - | A |
| benzo(a)anthracene | 5 80E-01 (4) | - | - | - | B2 |
| benzo(a)pyrene | 5 80E+00 (4) | - | 6 10E+00 (2) | - | B2 |
| benzo(b)fluoranthene | 5 80E-01 (4) | - | - | - | B2 |
| benzo(k)fluoranthene | 5 80E-01 (4) | - | - | - | B2 |
| benzoic acid | - | 4 00E+00 (1) | - | - | - |
| beryllium | | 5E-1 (2) | 8 4E-10 (1) | | B2 |
| bis(2-ethylhexyl)phthalate | 1 40E-02 (1) | 2 00E-02 (1) | - | - | B2 |
| bromodichloromethane | 6 20E-02 (1) | 2 00E-02 (1) | - | - | B2 |
| bromoform | 7 90E-03 (1) | 2 00E-02 (1) | 3 90E-03 (2) | - | B2 |
| butyl benzylphthalate | - | 2 00E-01 (1) | - | - | - |
| cadmium (food) | - | 1 0E-03 (1) | 6 30E+00 (1) | - | B1 |

**TABLE 2-3**
**ROCKY FLATS OU-2**
**TOXICITY FACTORS FOR**
**ORGANIC COMPOUNDS AND METALS**

| Analyte | Oral Slope Factor 1/(mg/kg/day) | Oral RfD (mg/kg/day) | Inhalation Slope Factor 1/(mg/kg/day) | Inhalation RfD (mg/kg/day) | EPA Cancer Weight Evidence |
|---|---|---|---|---|---|
| cadmium (water) | - | 5 00E-04 (1) | 6 30E+00 (1) | - | B1 |
| carbon tetrachloride | 1 30E-01(1) | 7 00E-04 (1) | 5 25E-02 (1) | - | B2 |
| chlorobenzene | - | 2 00E-02 (1) | - | 5 00E-03 (3) | - |
| chloroethane | - | - | - | 3 00E+00 (1) | - |
| chloroform | 6 10E-03 (1) | 1 00E-02 (1) | 8 00E-02 (1) | - | B2 |
| chloromethane | 1 30E-02 (2) | - | 6 30E-03 (2) | - | C |
| chromium III | - | 1 00E+00 (1) | - | - | - |
| chrysene | 5 80E-02 (4) | - | - | - | B2 |
| cis-1,2-dichloroethene | - | 1 00E-02 (2) | - | - | - |
| cis-1,3-dichloropropene* | - | 3 00E-04 (1) | - | 5 00E-03 (1) | B2 |
| cumene | - | 4 00E-02 (1) | - | 3 00E-03 (2) | - |
| cyanide | - | 2 00E-02 (1) | - | - | - |
| di-n-butylphthalate | - | 1 00E+01 (1) | - | - | - |
| di-n-octylphthalate | - | 2 00E-02 (2) | - | - | - |
| dibromomethane | - | 1 00E-02 (3) | - | - | - |
| dichlorodifluoromethane | - | 2 00E-01 (1) | - | 5 00E-02 (3) | - |
| diethyl phthalate | - | 8 00E-01 (1) | - | - | - |
| ethylbenzene | - | 1 00E-01 (1) | - | 3 00E-01 (1) | - |
| fluoranthene | - | 4 00E-02 (1) | - | - | - |
| fluorene | - | 4 00E-02 (1) | - | - | - |
| heptachlor epoxide | 9 10E+00 (1) | 1 30E-05 (1) | 9 10E+00 (1) | - | B2 |
| hexachlorobutadiene | 7 80E-02 (1) | - | 7 80E-02 (2) | - | C |
| hexachloroethane | 1 40E-02 (1) | 1 00E-03 (1) | 1 40E-02 (1) | | C |
| indeno(1,2,3-cd)pyrene | 5 80E-01 (4) | - | - | - | B2 |
| manganese | - | 1 00E-01 (3) | - | 1 10E-04 (1) | - |
| mercury | - | 3 00E-04 (2) | - | 9 0E-05 (2) | - |
| methylene chloride | 7 50E-03 (1) | 6 00E-02 (1) | 1 60E-03 (1) | 9 0E-01 (2) | B2 |
| molybdenum | - | 5 00E-03 (1) | - | - | - |
| N-nitrosodiphenylamine | 4 90E-03 (1) | - | - | - | B2 |
| naphthalene | - | 4 00E-02 (2) | - | - | - |
| nickel | | 2 00E-2 (2) | | | |
| o-chlorotoluene | - | 2 00E-02 (1) | - | - | - |
| p-xylene | - | 2 00E+00 (1) | - | - | - |
| pentachlorophenol | 1 20E-01(1) | 3 00E-02 (1) | - | - | B2 |
| pyrene | - | 3 00E-02 (1) | - | - | - |
| selenium | | 5 00E-3 (2) | | | |
| silver | - | 5 00E-03 (1) | - | - | - |
| strontium | | 8 8E-1 (2) | | | |
| styrene | - | 2 00E-01 (1) | - | 3 00E-01 (1) | - |
| tetrachloroethene | 5 10E-02 (3) | 1 00E-02 (1) | 1 80E-03 (3) | - | B2 |
| thallium | - | 7 00E-05 (2) | - | - | - |

**TABLE 2-3**
**ROCKY FLATS OU-2**
**TOXICITY FACTORS FOR**
**ORGANIC COMPOUNDS AND METALS**

| Analyte | Oral Slope Factor 1/(mg/kg/day) | Oral RfD (mg/kg/day) | Inhalation Slope Factor 1/(mg/kg/day) | Inhalation RfD (mg/kg/day) | EPA Cancer Weight Evidence |
|---|---|---|---|---|---|
| tin | | 6 00E-02 (2) | | | |
| toluene | - | 2 00E-01 (1) | - | 1 10E-01 (1) | - |
| trans-1,2-dichloroethene | - | 2 00E-02 (1) | - | - | - |
| trichloroethene | 1 10E-02 (3) | - | 5 95E-03 (3) | - | B2 |
| vinyl chloride | 1 90E+0 (1) | - | 3 00E-01 (1) | - | A |
| zinc | - | 2 00E-01(2) | - | - | - |

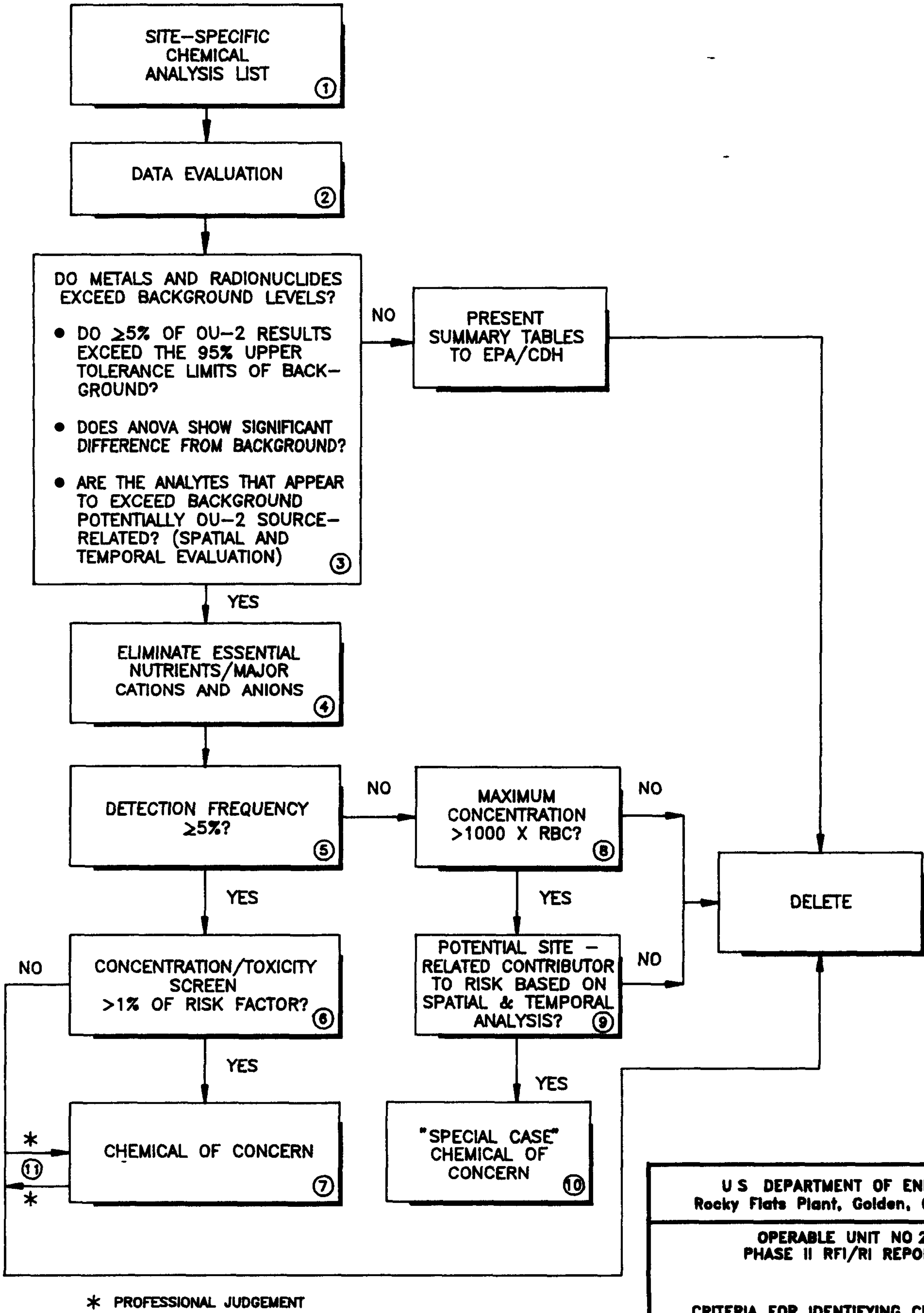
Sources
1 = IRIS
2 = HEAST 1992 (including supplements)
3 = HEAST 1991
4 = EPA Region IV Guidance, February 1992
* Values are for 1,3-dichloropropene No data for individual isomer
A = Human carcinogen
B1 = Probable human carcinogen (limited human data)
B2 = Probable human carcinogen (animal data only)
C = Possible human carcinogen
- = Not classifiable or not carcinogenic

**TABLE 2-4**
**ROCKY FLATS PLANT OU-2**
**TOXICITY FACTORS**
**FOR RADIONUCLIDES**

| Analyte | Oral Slope Factor (Risk/pCi) | Inhalation Slope Factor (Risk/pCi) | External Slope Factor (Risk/yr/pCi/g) | EPA Cancer Weight of Evidence |
|---|---|---|---|---|
| Americium 241 | 2 4E-10 | 3 2E-08 | 4 9E -09 | A |
| Cesium 134 | 4 1E-11 | 2 8E-11 | 5 2E-06 | A |
| Cesium 137 | 2 8E-11 | 1 9E-11 | 0 0E+00 | A |
| Plutonium 238 | 2 2E-10 | 3 9E-08 | 2 8E-11 | A |
| Plutonium 238 | 2 3E-10 | 3 8E-08 | 1 7E-11 | A |
| Plutonium 240 | 2 3E-10 | 3 8E-08 | 2 7E-11 | A |
| Radium 226 | 1 2E-10 | 3 0E-09 | 1 2E-08 | A |
| Radium 228 | 1 0E-10 | 6 6E-10 | 0 0E+00 | A |
| Strontium 89 | 3 0E-12 | 2 9E-12 | 4 7E-10 | A |
| Strontium 90 | 3 3E-11 | 5 6E-11 | 0 0E+00 | A |
| Tritium | 5 4E-14 | 7 8E-14 | 0 0E+00 | A |
| Uranium 233,234 * | 1 6E-11 | 2 6E-08 | 3 0E-11 | A |
| Uranium 235 | 1 6E-11 | 2 5E-08 | 2 4E-07 | A |
| Uranium 238 | 1 6E-11 | 2 40E-08 | 2 10E-11 | A |

Source HEAST 1992

A = Class A (human) carcinogen
* = Slope factors shown are for U-234




U S DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO 2
PHASE II RFI/RI REPORT

CRITERIA FOR IDENTIFYING CHEMICALS OF CONCERN FOR THE ROCKY FLATS OU2 HUMAN HEALTH RISK ASSESSMENT

FIGURE 2-1 JULY 1993

# 3.0
# GROUNDWATER CHEMICALS OF CONCERN

## 3.1 DATA EVALUATION

Chemicals of concern in groundwater were selected using the data sets identified in Table 2-2 Samples collected in the 2nd through 4th quarter 1991 and the 1st through 3rd quarter 1992 were used to evaluate volatile organic compounds, pesticides, PCBs, metals, and radionuclides Samples collected in the 4th quarter 1992 and the 1st and 2nd quarters 1992 were used to evaluate semivolatile organic compounds (semivolatile data were not available prior to 4th quarter 1991, no 3rd quarter 1992 data were received for semivolatiles) Monitoring well locations are shown in Figure 3-1

The data received from RFEDs were reviewed and edited using the steps and criteria outlined in Section 2 1 to develop a data set of environmental samples for further evaluation Groundwater data were then divided into two sets for selection of chemicals of concern (1) analytical results from wells screened in the No 1 Sandstone and (2) analytical results from all UHSU wells (i e , wells in the No 1 Sandstone, alluvium, colluvium, and valley fill) The No 1 Sandstone could support a drinking water well, under a hypothetical future residential development scenario, future residents could be exposed to OU-2 contaminants through ingestion of water from the No 1 Sandstone Therefore, analytical results from the No 1 Sandstone are used to select chemicals of concern for an on-site residential groundwater ingestion scenario to be evaluated in the risk assessment

The alluvium, colluvium, and valley fill are relatively thin and discontinuous, and occur on slopes (colluvium), these units have low yields and are only intermittently saturated (see Appendix C) These units cannot provide drinking water and were therefore not included as exposure media for on-site residential groundwater ingestion exposures However, analytical results from samples collected from monitoring wells in the alluvium, colluvium, valley fill, and No 1 Sandstone were used to evaluate contaminant migration through groundwater to surface water in Woman Creek and Walnut Creek These units are referred to collectively as the UHSU

A note on methylene chloride. Methylene chloride was detected in about 26 percent of the groundwater samples in concentrations ranging from 0 2 μg/L to 3900 μg/L Review of analytical results for methylene chloride in groundwater suggests that methylene chloride is not an environmental contaminant at the high concentrations reported for some samples

Methylene chloride is a common laboratory contaminant, as is acetone and bis(2-ethylhexyl)phthalate The methylene chloride results are given special attention since the compound is relatively toxic and could be identified as a chemical of concern if included in a concentration/toxicity screen If the identification were inaccurate (i e, if the methylene chloride probably results from laboratory procedures rather than waste sources), this could result in omitting other compounds from the risk assessment that are actual environmental contaminants

The highest results for methylene chloride were reported from 1991 wells sampled in the 4th quarter 1991 and 1st quarter of 1992 These samples were analyzed by the volatiles method 502 2, but the data were not validated because of the absence of an established validation process Concentrations in these samples ranged from approximately 4 to 3900 $\mu$g/L In subsequent sampling rounds in these wells, methylene chloride was either non-detect or, in a few cases, detected at much lower concentrations For example, in samples from well 7391 methylene chloride was reported at 3900 $\mu$g/L in 1st quarter 1992 and at 8 $\mu$g/L in 2nd quarter 1992 (both analyzed by method 502 2) In samples from well 11691, it was reported at 3000 $\mu$g/L in 1st quarter 1992 but was non-detect in the 3rd quarter 1992 (detection limit = 0 2 $\mu$g/L) In two samples from well 12691 collected in 1st quarter 1992, methylene chloride was reported at a concentration of 140 $\mu$g/L in one sample and was non-detect in the other (detection limit = 0 01 $\mu$g/L) This pattern is consistent for most of the wells sampled and analyzed by this method

Because methylene chloride was usually not detected in subsequent sampling rounds where a previous high concentration was reported, methylene chloride is not considered a groundwater contaminant in these wells There is no evidence of a plume of methylene chloride contamination, because other positive results are not spatially related. In order to address the possibility that methylene chloride is a local contaminant in some source areas, methylene chloride is included in concentration/toxicity screens to identify chemicals of concern using the maximum concentration reported in a well where methylene chloride was detected in more than one sampling round (excluding the reported value of 3900 $\mu$g/L in well 7391) This concentration is 38 $\mu$g/L detected in well 3687 in the 1st quarter 1992 Methylene chloride was reported in subsequent samples from this well at concentrations of 5 and 11 $\mu$g/L

## 3.2 BACKGROUND COMPARISON FOR INORGANIC COMPOUNDS

The comparison of OU-2 data for metals and radionuclides detected in groundwater to background data is presented in Appendix A The results are summarized in Tables 3-1 through 3-4 Tables 3-1 and 3-2 show the results for total (unfiltered) metals and radionuclides in the No 1 Sandstone Tables 3-3 and 3-4 show the results for dissolved (filtered fraction) metals and radionuclides in the UHSU Total inorganics in the No 1 Sandstone were evaluated as chemicals of concern for risk associated with on-site groundwater ingestion, and dissolved inorganics were evaluated in the UHSU for migration of contaminants in groundwater Metals and radionuclides that exceeded background and that were identified as potential OU-2 contaminants based on data evaluation were included in concentration/toxicity screens to select chemicals of concern for use in risk assessment

Metals and radionuclides were eliminated from further consideration (i e , were considered to be within background range) if less than 5 percent of the OU-2 data exceeded the 95% UTL of background and if the ANOVA analysis showed no significant difference from background ($p < 0.05$) Metals and radionuclides that appear to exceed background by one or both of the tests were retained for inclusion in a concentration/toxicity screen, or for further evaluation of the spatial and temporal distribution of elevated concentrations to identify potential OU-2 contaminants This was done in order to eliminate analytes from further consideration that are not actual site contaminants It is important that risk assessment and the selection of remedies be focussed on actual site contaminants that could threaten public health or the environment rather than on naturally occurring elements or trace contaminants that may be detected infrequently at elevated concentrations but are not characteristic of site contamination

### 3.2.1 No. 1 Sandstone

<u>Total Metals</u>

Table 3-1 shows the results of the background comparison for total metals in No 1 Sandstone On the basis of both statistical tests, the following metals were concluded not to exceed background levels antimony, beryllium, cadmium, cesium, chromium, cobalt, copper, lithium, molybdenum, nickel, selenium, silver, thallium, tin, and vanadium Metals in the No 1 Sandstone with widespread elevated concentrations that are potentially related to contaminant plumes in OU-2 are barium and manganese, based on results of both total and filtered samples (see Appendix D) These metals are widely distributed and consistently found at elevated concentrations at known source areas The presence of these metals in elevated concentrations in dissolved phase may be due to leaching of native materials from soil rather than from metal-bearing wastes On the basis of spatial, temporal, and other data evaluation, the following inorganic compounds are not considered site-related contaminants in the No 1 Sandstone aluminum, arsenic, cyanide, lead, mercury, strontium, and zinc The reasons are discussed below

Metals Eliminated as Contaminants
on the Basis of Spatial/Temporal Evaluation
No 1 Sandstone

Aluminum. Elevated concentrations of total aluminum (up to 128,000 $\mu g/L$) were detected in numerous samples from wells screened in the No 1 Sandstone Aluminum is a ubiquitous and naturally occurring element in soils and water Many of these samples also contained elevated concentrations of iron and other rock-forming elements The elevated aluminum concentrations are probably associated with the physical characteristics of the samples (e g , suspended solids) rather than to chemical releases in OU-2 because the dissolved-phase concentrations (see Appendix D) were below background range Since there is no evidence of a dissolved-phase plume, aluminum is not considered a contaminant in the No 1 Sandstone groundwater

Arsenic Total (unfiltered) arsenic was detected in 77 percent of the No 1 Sandstone groundwater samples Arsenic is a common, naturally occurring constituent in soils and groundwater Arsenic was detected in concentrations above the background UTL of 7 $\mu g/L$ in only 5 of 79 samples from the No 1 Sandstone (The background maximum is also 7 $\mu g/L$ ) Concentrations above the background UTL ranged from 8 to 11 4 $\mu g/L$, these are not greatly above background levels The maximum concentration of 11 4 $\mu g/L$ was observed in a sample from well 12191, which is located in the NE Trenches Area near Trench T-3 (IHSS 110) Arsenic was also detected above the background UTL in two other samples from wells that are in the NE Trenches Area but are not associated with trenches wells 3691 (8 3 $\mu g/L$) and well 3791 (8 $\mu g/L$) However, concentrations above background UTL in these wells were observed in only one of six sampling rounds and are, therefore, temporally isolated Furthermore, arsenic was not detected above background in well 3391, which is located downgradient of well 12191 and upgradient of wells 3691 and 3791 The other detection of arsenic above the background UTL was at well 10991 (9 4 $\mu g/L$) This well is located in the East Spray Fields This is the only No 1 Sandstone well in the area Alluvial wells in the area did not contain elevated concentrations of arsenic (with the exception of a temporally isolated observation of 9 $\mu g/L$ in well 5191) Based on the spatial and temporal distribution and infrequency of observations above the background UTL, arsenic is not considered a contaminant in No 1 Sandstone groundwater

Cyanide Cyanide concentrations exceeded the background UTL of 6 $\mu$g/l (background maximum = 8 5 $\mu$g/L) in three unrelated locations well 1491 (8 5 $\mu$g/L), well 3687 (12 5 $\mu$g/L), and well 13191 (20 7 $\mu$g/L) The rare and scattered occurrences of concentrations somewhat above background range indicate that elevated cyanide is not characteristic of groundwater in the No 1 Sandstone and that it is not a chemical of concern for OU-2

Lead Elevated concentrations of total lead (up to 171 $\mu$g/L) were detected in samples from several wells screened in the No 1 Sandstone in the NE Trenches Area, in the Mound Area, and west of the 903 Pad However, most of these samples also contained elevated concentrations of total iron, aluminum, and lithium, which are rock-forming elements Dissolved concentrations of these elements were not elevated above background levels (see Appendix D), and there is no evidence of a dissolved-phase plume For example, at two wells with elevated total lead concentrations (well 11891 at 171 $\mu$g/L and in well 3691 at 86 $\mu$g/L), dissolved lead was non-detect at a reporting limit of 3 $\mu$g/L In addition, lead is within background levels in soils (see Tables 4-1 and 5-1) The elevated total lead concentrations in the groundwater samples are likely to be naturally occurring and related to suspended solids in the water samples rather than to leaching resulting from OU-2 contamination because there is no evidence of a dissolved-phase plume or of elevated lead in soils

Mercury Mercury was detected in 15 percent of the samples analyzed (maximumk concentration = 0 8 $\mu$g/L) The maximum concentration was detected in well 5691 in the NE Trench Area The background UTL is 0 2 $\mu$g/L Mercury was also detected in three wells (2387, 1791, and 1491) in the Mound Area, in concentrations ranging from 0 27 to 0 62 $\mu$g/L, these wells are screened in the No 1 Sandstone However, the upper paired wells were non-detect for mercury at a reporting limit of 0 2 $\mu$g/L Dissolved-phase mercury was not elevated above background levels, and there is no evidence of a contaminant plume Mercury is not considered a contaminant in groundwater because (1) the elevated concentrations are low (0 25 to 0 8 $\mu$g/L), (2) dissolved-phase concentrations are within background levels, (3) elevated concentrations occur in some wells screened at the base of the No 1 Sandstone but not in paired wells screened near the top of the sandstone, and (4) only one well (11691 in the NE Trench Area) had mercury detected in more than one sampling event

Strontium Concentrations for total strontium were somewhat elevated in 6 percent of the samples collected from wells screened in the No 1 Sandstone Elevated concentrations ranged from 1010 $\mu$g/L to 1370 $\mu$g/L (background UTL = 921 $\mu$g/L) Strontium was detected at somewhat elevated concentrations in some wells potentially related to source areas These latter wells include well 1491 at the 903 Pad (1040 $\mu$g/L) and well 291 near the inner East Gate (1070 μg/L) Comparable concentrations also occur in wells that are unrelated to source areas (such as wells 286 and 41591, both at Indiana Avenue) The filtered fraction was also elevated in most samples where total strontium was elevated Because strontium is found in wells unrelated to source areas at concentrations comparable to those found near source areas, maximum concentrations are only somewhat above background, and there is no evidence of a total or dissolved-phase plume, strontium is not considered a contaminant in No 1 Sandstone groundwater

Zinc Zinc was detected in 98 percent of the groundwater samples collected It is a ubiquitous and naturally occurring element in soils and water The maximum concentration of zinc observed was 839 μg/L, which is below the background UTL of 1023 μg/L Furthermore, the mean concentration of total zinc in the No 1 Sandstone (133 μg/L) is not very different than the mean concentration of background (127 μg/L) Therefore, zinc is not considered a contaminant in No 1 Sandstone groundwater

**Radionuclides**

Table 3-2 summarizes the background comparison for total radionuclides in the No 1 Sandstone Radionuclides considered to be OU-2 contaminants in the No 1 Sandstone based on the statistical comparison to background data are americium-241 and plutonium-239/240

Cesium-137 is also retained as a potential chemical of concern in No 1 Sandstone groundwater Cesium-137 was detected at concentrations above the background UTL of 0 83 pCi/L in 7 of 49 (14 percent) No 1 Sandstone unfiltered groundwater samples analyzed for this radionuclide The maximum concentration was 1 66 pCi/L, detected in well 12191 at Trench T-3 Cs-137 was also detected above background UTL in well 12491 (0 88 and 1 24 pCi/L), well 3791 (1 07 pCi/L), well 12091 (1 15 pCi/L), well 2091 (0 96 pCi/L), and well 3791 (1 07 pCi/L) Concentrations above background UTL occurred only once in three to five sampling events, except in well 12191, where two of five samples had concentrations above the background UTL Wells upgradient of 12491 did not contain elevated concentrations of Cs-137 Although it is probable that some or most sample results represent naturally occurring Cs-137, this radionuclide is retained as a possible contaminant in No 1 Sandstone groundwater because of the percentage of results that exceeded the background UTL

Total (unfiltered) concentrations of radium-226, strontium-89,90, and the uranium isotopes do not exceed background levels in the No 1 Sandstone using both statistical tests, and these are not considered groundwater contaminants Total (as opposed to dissolved) isotopes were only analyzed for in four groundwater samples collected in the Mound Area

### 3.2.2 UHSU

Table 3-3 shows the results of the background comparison for dissolved metals in the UHSU, including the No 1 Sandstone Dissolved-phase constituents are assessed in the UHSU rather than total metals because dissolved-phase contaminants may be transported in groundwater to exposure points in Woman or Walnut Creeks

Metals

On the basis of the statistical tests, the following metals were concluded not to exceed background levels aluminum, arsenic, beryllium, cadmium, cesium, cobalt, copper, lead, lithium, mercury, molybdenum, selenium, silver, thallium, tin, and vanadium On the basis of spatial and temporal evaluation, the following metals are not considered site-related contaminants in the UHSU antimony, chromium, nickel, strontium, and zinc The reasons are discussed below Other metals in UHSU groundwater with widespread elevated concentrations that are potentially related to contaminant plumes in OU-2 are barium and manganese

Metals Eliminated as Contaminants
on the Basis of Spatial/Temporal Evaluation
UHSU

Antimony Antimony concentrations are evenly distributed and unrelated to source areas Detected concentrations range from 8 to 88 $\mu$g/L, the maximum value was detected at well 286 at Indiana Street Other detected values were below the 95% UTL of background (46 $\mu$g/L) and appear to have no relationship to source areas

Chromium Only six percent of the results exceeded the background UTL of 14 $\mu$g/L and chromium did not exceed background by the ANOVA test The OU-2 maximum detected value of 23 $\mu$g/L is equivalent to the background maximum (also 23 $\mu$g/L), and the background mean (6 $\mu$g/L) exceeds the OU-2 mean (5 $\mu$g/L) Five samples with elevated concentrations (15 to 23 $\mu$g/L) were from wells in the NE Trenches Area (wells 2587, 3686, 3687, 4286) However, upgradient wells do not exhibit elevated concentrations of chromium, and only well 3687 had more than one sampling event with a concentration that exceeded the background UTL Therefore, chromium is not retained as a potential chemical of concern in the UHSU

Nickel  Eight sample results (6 percent) exceeded the background UTL of 25 $\mu$g/L  Elevated concentrations of nickel were detected in four samples from well 2987 (239 to 1210 $\mu$g/L), one sample each from well 3686 (287 $\mu$g/L) and well 6586 (65 $\mu$g/L), and in two samples from well 286 at Indiana Street (46 and 50 $\mu$g/L)  The elevated concentrations do not appear to be associated with source areas in OU-2 or with a contaminant plume  Other detected values ranged from 2 to 25 $\mu$g/L, which are equal to or below the background UTL of 25 $\mu$g/L  Because elevated concentrations occurred in only three wells within OU-2 (not counting well 286 at Indiana Street), all of which are screened in the colluvium or valley fill, and because elevated concentrations do not appear to be associated with source areas, nickel is not considered a contaminant in the UHSU

Strontium  Only 2 percent of the strontium results exceeded the background UTL of 2148 $\mu$g/L (background maximum = 8730 $\mu$g/L)  The highest concentrations of strontium were detected in samples collected from wells 286 and 41591 at Indiana Street (2000 to 2290 $\mu$g/L), in well 7391 near a source trench (about 3000 $\mu$g/L in two samples), and in well 3686 (2020 $\mu$g/L), which is screened in the valley fill in Walnut Creek  Strontium is otherwise evenly distributed throughout OU-2 in concentrations of less than 1000 $\mu$g/L  Because strontium was detected in comparable concentrations in wells near source areas and at locations distant from source areas,  it is not considered an OU-2 contaminant

Zinc  Zinc was detected above the background UTL concentration of 51 $\mu$g/L in only 3 of nearly 200 samples, and zinc does not exceed background by the UTL comparison  The maximum concentration of 759 $\mu$g/L was observed in well 05691  This extreme concentration appears to have biased the ANOVA  Other elevated concentrations were 56 $\mu$g/L in well 2387 and 157 g/L in well 12987, these concentrations are near or below the background maximum of 137 $\mu$g/L  Concentrations exceeding the UTL were observed only once in several sampling rounds and do not appear to be related to known source areas  Zinc is not considered a contaminant in groundwater in OU-2

## Radionuclides

Table 3-4 summarizes the background comparison for dissolved radionuclides in the UHSU For a number of the analytes, few background data were available for comparison  Americium-241, plutonium-239,240, tritium, and uranium-238 are considered potential contaminants in UHSU groundwater  According to the results of the statistical tests, uranium-238 did not exceed background levels  Nevertheless, this radionuclide is considered a potential contaminant for the following reasons  The background UTL is 37 pCi/L, and the background maximum is

136 pCi/L However, all but three background concentrations were below 16 pCi/L Background results higher than 16 pCi/L were all measured in well 205589 (100 to 136 pCi/L) Uranium-238 was detected in OU-2 samples in concentrations ranging from 0 17 pCi/L to 76 pCi/L None of the OU-2 results exceeded the background maximum of 136 pCi/L, but two results exceeded the background UTL of 37 pCi/L Several groundwater sampling locations in the 903 Pad area (wells 687, 7391, and 8891) and well 2091 in the Mound Area had uranium-238 concentrations ranging from 18 to 75 pCi/L in more than one sampling round These concentrations exceed all background results except the background sample results from well 205589 Because of the location of elevated concentrations in known source areas in OU-2, uranium-238 is considered as a potential contaminant in UHSU groundwater

Other radionuclides were eliminated from further consideration for the reasons discussed below

Radionuclides Eliminated as Contaminants
on the Basis of Spatial/Temporal or Other Data Evaluation
UHSU

Cesium-137 Cesium-137 was detected in only 2 of 11 samples at concentrations of 0 25 pCi/L (well 11691) and 0 5 pCi/L (well 3091) No background data are available for comparison The few data available do not support identifying Cesium-137 as a groundwater contaminant

Radium-226. Radium-226 was detected in UHSU groundwater (filtered fraction) in concentrations ranging from 0 15 to 2 8 pCi/L The background UTL is 1 8 pCi/L and the background maximum value is 3 pCi/L Only 2 percent of the OU-2 data (i e, one result) exceeded the background UTL, but this result (2 8 pCi/L) was below the background maximum Therefore, radium-226 is not considered an OU-2 contaminant

Strontium-89-90. Strontium-89,90 was detected in UHSU groundwater (filtered fraction) in concentrations ranging from 0 009 to 2 1 pCi/L Seven percent of the sample results exceeded the background UTL of 0 82 pCi/L Concentrations exceeding the background UTL occurred in only one of several sampling events per well Because the occurrences of elevated concentrations are temporally isolated events, this radionuclide is not considered a contaminant in OU-2 groundwater

Uranium-233-234 Uranium-233,234 did not exceed background by either statistical test Ur-233,234 was detected in UHSU groundwater (filtered fraction) in concentrations ranging from

0 18 to 43 pCi/L None of these results exceed the background UTL of 53 pCi/L The background maximum was 200 pCi/L, but most background sample results were less than 18 pCi/L OU-2 data are consistent with the background data, in that most of the OU-2 results were below 11 pCi/L, with four results in the 20 to 24 pCi/L range, and the maximum at 43 pCi/L Ur-233,234 concentrations are within background levels and the isotopes are not considered contaminants in groundwater

Uranium-235 Uranium-235, like uranium-233,234, was not detected in any sample above the background UTL of 1 7 pCi/L The background maximum was 4 8 pCi/L, but most background concentrations were less than 1 pCi/L The OU-2 maximum was 1 5 pCi/L, but most OU-2 concentrations were also less than 1 pCi/L Uranium-235 is considered to be within background levels and is not a contaminant in groundwater

## 3.3 FREQUENCY OF DETECTION

Organic compounds detected at a frequency of 5 percent or greater were considered potential chemicals of concern These compounds are listed in Tables 3-5 (No 1 Sandstone) and 3-6 (UHSU) and are included in the concentration/toxicity screens for groundwater Frequency of detection was evaluated separately for the No 1 Sandstone and UHSU for consistency with the evaluation of metals and radionuclides

Infrequently detected compounds (detected at less than 5 percent frequency) are listed in Tables 3-7 and 3-8 Concentrations of infrequently detected organic compounds were further evaluated as described in Section 3 5 to identify "special case" chemicals of concern for evaluation in the risk assessment

## 3.4 CONCENTRATION/TOXICITY SCREENS

Concentration/toxicity screens were used to identify chemicals of concern in groundwater to be evaluated in the quantitative human health risk assessment The screening process permits selecting chemicals, based on concentration and toxicity, that could contribute significantly to risk and identifies chemicals that can be eliminated from further consideration because they contribute insignificantly to overall risk The screen was performed for all inorganic constituents identified as potential contaminants and for all organic compounds detected at a frequency of 5 percent or greater The concentration/toxicity screen process was explained in Section 2 4 In performing the concentration/toxicity screens for organic compounds detected in groundwater, if both inhalation and oral toxicity factors were available for organic compounds, the toxicity value that resulted in the highest relative risk value was used For evaluation of metals and radionuclides in groundwater, only oral slope factors were used

Results of the screen for the No 1 Sandstone are shown in Tables 3-9 (Noncarcinogenic Effects), 3-10 (Carcinogenic Effects), and 3-11 (Radionuclides) Results of the screen for the UHSU are shown in Tables 3-12 (Noncarcinogenic Effects), 3-13 (Carcinogenic Effects), and 3-14 (Radionuclides) All chemicals that comprise approximately 99 percent of the total risk factor are identified as chemicals of concern to be evaluated in the risk assessment

The following chemicals were identified as chemicals of concern for both the No 1 Sandstone and the UHSU as a whole carbon tetrachloride, chloroform, 1,1-dichloroethene, cis-1,2-dichloroethene, trichloroethene, tetrachlorethene, americium-241, and plutonium-239/240 Manganese and barium are identified as additional chemicals of concern in the No 1 Sandstone Uranium-238, and tritium are identified as additional chemicals of concern in the UHSU

## 3.5 EVALUATION OF INFREQUENTLY DETECTED COMPOUNDS

As stated in Section 3 2, compounds detected at less than 5 percent frequency can usually be eliminated from further consideration because the potential for exposure is low However, these compounds were further screened so as not to neglect infrequently detected compounds that could contribute significantly to risk if exposure were to occur In this screen, maximum concentrations of infrequently detected compounds were compared to risk-based screening values using the approach outlined in Section 2 5 and described in greater detail in Appendix B Complete results of the evaluation are shown in Table B-6 The evaluation shows that the following two infrequently detected compounds have maximum concentrations that exceed the screening values used in the analysis

1,2-dibromoethane
vinyl chloride

The compound 1,2-dibromoethane was detected in 2 of 170 groundwater samples at concentrations of 1 8 $\mu$g/L (well 6691 in the 903 Pad) and at 13 $\mu$g/L (well 7391, IHSS 109) Well 6691 is screened in the Rocky Flats alluvium, and well 7391 is screened in the colluvium Both wells are in or near contaminant source areas where other solvents have been detected The samples with positive results were collected in May 1992 These wells were also sampled in November 1992 (4th quarter) and 1,2-dibromoethane was not detected, although reporting limits were elevated, so the results are inconclusive 1,2-Dibromoethane is not characteristic of groundwater contamination at OU-2 because it is so infrequently detected However, it will be evaluated in the risk assessment as a "special-case" chemical of concern

Vinyl chloride was detected at approximately 4 percent frequency of detection (10 samples out of about 280) The highest concentrations (380 to 860 $\mu$g/L) were detected in several samples collected at well 3586 This well is located at the northern boundary of OU-2 near the discharge from the Protected Area and near a seep that is being investigated under a separate program Vinyl chloride was not detected in OU-2 upgradient of this well Therefore, vinyl chloride detected in this well is probably not related to source areas in OU-2 Vinyl chloride was detected in much lower concentrations (2 to 3 $\mu$g/L) in samples from well 7391, where it is co-located with other solvents Vinyl chloride is included as a "special-case" chemical of concern for OU-2

## 3 6 SUMMARY OF CHEMICALS OF CONCERN IN GROUNDWATER

Summary lists of chemicals of concern identified by the concentration/toxicity screens are shown in Tables 3-15 (No 1 Sandstone) and 3-16 (UHSU)

Some chemicals detected in groundwater do not have EPA-established toxicity factors and cannot be evaluated in the concentration/toxicity screen or other risk-based screening for infrequently detected compounds These chemicals are listed in Table 3-17 They will be evaluated qualitatively in the risk assessment

**TABLE 3-1**

**ROCKY FLATS PLANT OU-2**
**SUMMARY OF BACKGROUND COMPARISON**
**TOTAL METALS IN GROUNDWATER, µg/L**
**NO 1 SANDSTONE**

| Analyte | DF % (1) | % Data > 95% UTL (1) | ANOVA p (2) | | Potential Contaminant? No (3) | Potential Contaminant? Yes (4) | Spatial /Temporal / Other (See Text) | OU-2 Contam-inant? |
|---|---|---|---|---|---|---|---|---|
| Aluminum | 100 | 82 | <0 01 | | | X | Widely distributed, low dissolved concentrations | No |
| Antimony | 20 | 0 | 0 63 | * | X | | | No |
| Arsenic | 77 | 6 | 0 02 | * | | X | No spatial or temporal significance | No |
| Barium | 100 | 12 | <0 01 | | | X | Elevated total and dissolved concentrations in many wells near source areas | Yes |
| Beryllium | 63 | 0 | 0 08 | * | X | | | No |
| Cadmium | 36 | 0 | 0 89 | * | X | | | No |
| Cesium | 9 | 0 | 0 21 | * | X | | | No |
| Chromium | 75 | 0 | <0 01 | * | X | | | No |
| Cobalt | 68 | 0 | 0 01 | * | X | | | No |
| Copper | 83 | 0 | 0 28 | * | X | | | No |
| Cyanide | 44 | 16 | 0 88 | | | ? | Erratic hits, low frequency, no spatial significance | No |
| Lead | 99 | 65 | <0 01 | | | X | Widely distributed, low dissolved conc , no dissolved plume | No |
| Lithium | 93 | 0 | 0 04 | * | X | | | No |
| Manganese | 100 | 40 | <0 01 | | | X | Elevated total and dissolved concentrations in many wells near source areas | Yes |
| Mercury | 15 | 15 | 0 03 | * | X | | Erratic hits, low frequency, no dissolved plume | No |
| Molybdenum | 49 | 0 | 0 22 | * | X | | | No |
| Nickel | 85 | 0 | 0 72 | * | X | | | No |
| Selenium | 50 | 0 | 0 03 | * | X | | | No |
| Silver | 13 | 0 | <0 01 | * | X | | | No |
| Strontium | 99 | 6 | <0 01 | | | X | Elevated concentrations found far from source areas | No |
| Thallium | 15 | 0 | 0 56 | * | X | | | No |
| Tin | 21 | 0 | 0 28 | * | X | | | No |
| Vanadium | 100 | 0 | <0 01 | * | X | | | No |
| Zinc | 98 | 0 | <0 01 | * | ? | | All conc < bknd UTL Bknd mean (127 ug/l) is very close to OU-2 mean (133 ug/L) | No |

(1) Detection frequency and UTL comparison from Table A-1
(2) Table A-9 p < 0 05 is considered significant
(3) < 5% data exceeds 95% UTL and p > 0 05
(4) > 5% data exceeds 95% UTL and p < 0 05
? Either > 5% data exceeds 95% UTL or p < 0 05

* Background mean equals or exceeds OU-2 mean

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**TABLE 3-3**

**ROCKY FLATS PLANT OU-2**
**SUMMARY OF BACKGROUND COMPARISON**
**DISSOLVED METALS IN GROUNDWATER, µg/L**
**UHSU**

| Analyte | DF % (1) | % Data > 95% UTL (1) | ANOVA p (2) | Potential Contaminant? No (3) | Potential Contaminant? Yes (4) | Spatial/Temporal/Other (see text) | OU-2 Contaminant? |
|---|---|---|---|---|---|---|---|
| Aluminum | 74 | 0 | 0.58 * | X | | | No |
| Antimony | 17 | 9 | <0.01 | | X | Evenly distributed, unrelated to source areas | No |
| Arsenic | 11 | 1 | 0.37 * | X | | | No |
| Barium | 100 | 40 | <0.01 | | X | | Yes |
| Beryllium | 4 | 0 | 0.59 * | X | | | No |
| Cadmium | 11 | 2 | 0.44 | X | | | No |
| Cesium | 20 | 0 | <0.01 * | X | | | No |
| Chromium | 24 | 6 | <0.01 * | | ? | OU-2 max = bknd max, most results > bknd UTL occur in only one of several sampling rounds | No |
| Cobalt | 6 | 0 | 0.86 * | X | | | No |
| Copper | 25 | 2 | 0.01 * | X | | | No |
| Lead | 6 | 0 | <0.01 * | X | | | No |
| Lithium | 79 | 0 | <0.01 * | X | | | No |
| Manganese | 73 | 23 | <0.01 | | X | | Yes |
| Mercury | 3 | 0 | 0.14 * | X | | | No |
| Molybdenum | 45 | 1 | 0.26 * | X | | | No |
| Nickel | 31 | 6 | 0.16 | | ? | Comparable concentrations at source areas and non-source areas | No |
| Selenium | 36 | 0 | <0.01 * | X | | | No |
| Silver | 9 | 0 | <0.01 * | X | | | No |
| Strontium | 99 | 2 | <0.01 | | ? | Comparable concentrations at source areas and non-source areas | No |
| Thallium | 6 | 0 | 0.83 | X | | | No |
| Tin | 10 | 0 | <0.01 * | X | | | No |
| Vanadium | 69 | 0 | <0.01 * | X | | | No |
| Zinc | 67 | 3 | <0.01 | | ? | ANOVA biased by OU-2 outlier, no relation to source areas | No |

(1) Detection frequency and UTL comparison from Table A-3
(2) Table A-11 p < 0.05 is considered significant
(3) <5% data exceeds 95% UTL and p > 0.05
(4) > 5% data exceeds 95% UTL and p < 0.05

? Either >5% data exceeds 95% UTL or p <0.05
* Background mean equals or exceeds OU-2 mean.

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TABLE 3-4

**ROCKY FLATS PLANT OU-2**
**SUMMARY OF BACKGROUND COMPARISON**
**DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L**
**UHSU**

| Analyte | DF (1) | % Data > 95% UTL (1) | ANOVA p (2) | | Potential Contaminant? No (3) | Potential Contaminant? Yes (4) | Spatial/Temporal/Other (see text) | OU-2 Contam-inant? |
|---|---|---|---|---|---|---|---|---|
| Americium 241 | 10/10 | 30 | 0 74 | | | ? | Probable contaminant | Yes |
| Cesium 137 | 2/11 | - | - | | | ? | Few data to support identification as contaminant | No |
| Plutonium 239,240 | 10/10 | - | - | | | ? | Probable contaminant | Yes |
| Radium 226 | 52/53 | 2 | <0 01 | | | ? | OU-2 concentrations < bknd max | No |
| Strontium 89,90 | 165/184 | 7 | 0 99 | | | ? | Results > bknd UTL are temporally isolated | No |
| Tritium | 181/181 | 8 | 0 06 | | | ? | | ? |
| Uranium 233,234 | 230/230 | 0 | <0 01 | * | X | | All concentrations below background | No |
| Uranium 235 | 179/197 | 0 | 0 05 | * | X | | All concentrations below background | No |
| Uranium 238 | 224/224 | 1 | <0 01 | * | ? | | Retained based on data evaluation | Yes |

(1) Detection frequency and UTL comparison from Table A-4
(2) Table A-12 p < 0 05 is considered significant
(3) <5% data exceeds 95% UTL and p > 0 05
(4) > 5% data exceeds 95% UTL and p < 0 05
? Either > 5% data exceeds 95% UTL or p < 0 05
* Background mean equals or exceeds OU2 mean
- Analysis not performed See Tables A-4 and A-12

## TABLE 3-5

## ROCKY FLATS PLANT OU-2
## ORGANIC COMPOUNDS DETECTED AT
## 5% OR GREATER FREQUENCY
## NO. 1 SANDSTONE GROUNDWATER

| Chemical | Maximum Concentration mg/L | Detection Frequency % |
|---|---|---|
| 1,1,1,2-tetrachloroethane | 0 0026 | 6 |
| 1,1,1-trichloroethane | 0 13 | 39 |
| 1,1,2,2-tetrachloroethane | 0 0024 | 6 |
| 1,1-dichloroethane | 0 0034 | 26 |
| 1,1-dichloroethene | 0 036 | 34 |
| 1,1-dichloropropene | 0 0016 | 5 |
| 1,2-dichloroethene | 0 054 | 39 |
| acetone | 0 16 | 9 |
| benzene | 0 001 | 6 |
| bromochloromethane | 0 03 | 5 |
| bromodichloromethane | 0 018 | 9 |
| carbon tetrachloride | 4 5 | 63 |
| chloroform | 1 1 | 65 |
| cis-1,2-dichloroethene | 0 3 | 51 |
| methylene chloride | 3 | 40 |
| naphthalene | 0 044 | 10 |
| n-butyl benzene | 0 0013 | 5 |
| p-cymene | 0 00076 | 6 |
| tetrachloroethene | 13 | 79 |
| toluene | 0 013 | 11 |
| trans-1,2-dichloroethene | 0 025 | 13 |
| trichloroethene | 94 | 72 |
| bis (2-ethylhexyl) phthalate | 0 017 | 33 |
| benzoic acid | 0 056 | 6 |
| diethyl phthalate | 0 31 | 26 |
| di-n-butyl phthalate | 0 003 | 6 |

## TABLE 3-6

## ROCKY FLATS PLANT OU-2
## ORGANIC COMPOUNDS DETECTED AT 5% OR GREATER FREQUENCY
## UHSU GROUNDWATER

| Chemical | Maximum Concentration mg/L | Detection Frequency % |
|---|---|---|
| 1,1,1-trichloroethane | 0 54 | 24 |
| 1,1-dichloroethane | 0 19 | 15 |
| 1,1-dichloroethene | 0 26 | 23 |
| 1,2-dichloroethene | 0 17 | 32 |
| bromodichloromethane | 0 02 | 7 |
| carbon tetrachloride | 17 | 57 |
| chloroform | 1 7 | 58 |
| cis-1,2-dichloroethene | 1 4 | 46 |
| methylene chloride | 3 9 | 26 |
| tetrachloroethene | 13 | 67 |
| toluene | 0 01 | 9 |
| trans-1,2-dichloroethene | 0 03 | 11 |
| trichloroethene | 94 | 62 |
| bis(2-ethylhexyl)phthalate | 0 017 | 38 |
| diethylphthalate | 0 31 | 20 |
| naphthalene | 0 09 | 13 |
| heptachlor epoxide | 0 00007 | * |

* Reported in 1 of 2 samples analyzed

TABLE 3-7

ROCKY FLATS PLANT OU-2
ORGANIC COMPOUNDS DETECTED AT
LESS THAN 5% FREQUENCY
NO. 1 SANDSTONE GROUNDWATER

| | Maximum Concentration mg/L | Detection Frequency % |
|---|---|---|
| 1,1,2-trichloroethane | 0 0006 | 3 |
| 1,2,3-trichlorobenzene | 0 00003 | 3 |
| 1,2,4-trichlorobenzene | 0 0003 | 1 |
| 1,2-dichloroethane | 0 001 | 3 |
| 1,3-dimethylbenzene | 0 0002 | 3 |
| 4-methyl-2-pentanone | 0 01 | 4 |
| 1,2,4-trimethylbenzene | 0 0001 | 3 |
| 1,3,5-trimethylbenzene | 0 00009 | 3 |
| carbon disulfide | 0 0008 | 4 |
| chlorobenzene | 0 016 | 2 |
| chloroethane | 0 043 | 2 |
| chloromethane | 0 00029 | 2 |
| cis-1,3-dichloropropene | 0 013 | 2 |
| dibromomethane | 0 065 | 2 |
| dichlorodifluoromethane | 0 00058 | 3 |
| ethylbenzene | 0 015 | 2 |
| hexachlorobutadiene | 0 0012 | 4 |
| sec-butylbenzene | 0 00024 | 3 |
| styrene | 0 014 | 3 |
| total xylene | 0 053 | 3 |
| trichlorofluoromethane | 0 00057 | 4 |

## TABLE 3-8

## ROCKY FLATS PLANT OU-2
## ORGANIC COMPOUNDS DETECTED AT
## LESS THAN 5% FREQUENCY
## UHSU GROUNDWATER

| Chemical | Maximum Concentration mg/L | Detection Frequency % |
|---|---|---|
| 1,1,1,2-tetrachloroethane | 0 003 | 3 |
| 1,1,2,2-tetrachloroethane | 0 18 | 3 |
| 1,1,2-trichloroethane | 0 02 | 2 |
| 1,1-dichloropropene | 0 002 | 2 |
| 1,2,3-trichlorobenzene | 0 0003 | 2 |
| 1,2,3-trichloropropane | 0 002 | 2 |
| 1,2,4-trichlorobenzene | 0 002 | 2 |
| 1,2-dibromoethane | 0 01 | 1 |
| 1,2-dichlorobenzene | 0 0001 | <1 |
| 1,2-dichloroethane | 0 0073 | 3 |
| 1,2-dichloropropane | 0 02 | <1 |
| 1,2-dimethylbenzene (o-xylene) | 0 0002 | 3 |
| 1,3-dichlorobenzene | 0 002 | 2 |
| 1,3-dichloropropane | 0 0003 | 1 |
| 1,3-dimethylbenzene (m-xylene) | 0 0003 | 2 |
| 1,4-dichlorobenzene | 0 0003 | 1 |
| 2-hexanone | 0 005 | 2 |
| 4-methyl-2-pentanone | 0 01 | 2 |
| acetone | 0 16 | 4 |
| benzene | 0 005 | 5 |
| 1,2,4-trimethylbenzene | 0 0001 | 2 |
| 1,3,5-trimethylbenzene | 0 001 | 1 |
| benzoic acid | 0 056 | 4 |
| bromobenzene | 0 0003 | 1 |
| bromoform | 0 006 | 1 |
| chlorobenzene | 0 02 | 1 |
| chloroethane | 0 04 | 1 |
| chloromethane | 0 005 | 1 |
| cis-1,3-dichloropropene | 1 7 | 1 |
| dibromomethane | 1 7 | 2 |
| dichlorodifluoromethane | 0 0006 | 1 |
| ethylbenzene | 0 02 | 2 |
| hexachlorobutadiene | 0 0012 | 3 |
| n-butylbenzene | 0 001 | 2 |
| o-chlorotoluene | 0 003 | 0 05 |
| p-chlorotoluene | 0 0003 | <1 |

## TABLE 3-8
## (Concluded)

| | Maximum Concentration mg/L | Detection Frequency % |
|---|---|---|
| p-cymene | 0 0008 | 4 |
| 1,2-dibromo-3-chloropropane | 0 004 | 1 |
| sec-butylbenzene | 0 2 | 3 |
| sec-dichloropropane | 0 01 | 1 |
| styrene | 0 01 | 3 |
| tert-butylbenzene | 0 0004 | 1 |
| vinyl chloride | 0 86 | 3 |
| di-n-butylphthalate | 0 003 | 4 |

## TABLE 3-9

## ROCKY FLATS OU-2
## CONCENTRATION/TOXICITY SCREEN
## NO. 1 SANDSTONE GROUNDWATER
## NONCARCINOGENS
## (Organics and Total Metals)

| Chemical | Maximum Value (ppm) | Inhalation RFD | Oral RFD | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| carbon tetrachloride (1) | 4 5 | n/a | 7 00E-04 | 6 43E+03 | 8 06E-01 | 1 | 80 6 |
| tetrachloroethene (1) | 13 | n/a | 1 00E-02 | 1 30E+03 | 1 63E-01 | 2 | 96 8 |
| chloroform (1) | 1 1 | n/a | 1 00E-02 | 1 10E+02 | 1 38E-02 | 3 | 98 2 |
| manganese(3) | 4 92 | n/a | 1 00E-01 | 4 92E+01 | 6 17E-03 | 4 | 98 8 |
| barium (2,1) | 3 09 | n/a | 7 00E-02 | 4 41E+01 | 5 53E-03 | 5 | 99 4 |
| *cis-1,2-dichloroethene (2) | 0 3 | n/a | 1 00E-02 | 3 00E+01 | 3 76E-03 | 6 | 99 8 |
| 1,2-dichloroethene (2) | 0 054 | n/a | 9 00E-03 | 6 00E+00 | 7 52E-04 | 7 | 99 8 |
| 1,1-dichloroethene (1) | 0 036 | n/a | 9 00E-03 | 4 00E+00 | 5 01E-04 | 8 | 99 9 |
| acetone (1) | 0 16 | n/a | 1 00E-01 | 1 60E+00 | 2 00E-04 | 9 | 99 9 |
| 1,1,1-trichloroethane (2) | 0 13 | 3 00E-01 | 9 00E-02 | 1 44E+00 | 1 81E-04 | 10 | 99 9 |
| trans-1,2-dichloroethene (1 | 0 025 | n/a | 2 00E-02 | 1 25E+00 | 1 57E-04 | 11 | 99 9 |
| naphthalene (2) | 0 044 | n/a | 4 00E-02 | 1 10E+00 | 1 38E-04 | 12 | 100 0 |
| bromodichloromethane (1) | 0 018 | n/a | 2 00E-02 | 9 00E-01 | 1 13E-04 | 13 | 100 0 |
| bis(2-ethylhexyl)phthalate | 0 017 | n/a | 2 00E-02 | 8 50E-01 | 1 07E-04 | 14 | 100 0 |
| methylene chloride (2,1) | 0 04 | 9 00E-01 | 6 00E-02 | 6 67E-01 | 8 35E-05 | 15 | 100 0 |
| diethyl phthalate (1) | 0 31 | n/a | 8 00E-01 | 3 88E-01 | 4 86E-05 | 16 | 100 0 |
| toluene (1) | 0 013 | 1 10E-01 | 2 00E-01 | 1 18E-01 | 1 48E-05 | 17 | 100 0 |
| 1,1,1,2-tetrachloroethane ( | 0 0026 | n/a | 3 00E-02 | 8 67E-02 | 1 09E-05 | 18 | 100 0 |
| 1,1-dichloroethane (2,3) | 0 0034 | 1 40E-01 | 1 00E-01 | 3 40E-02 | 4 26E-06 | 19 | 100 0 |
| benzoic acid (1) | 0 056 | n/a | 4 00E+00 | 1 40E-02 | 1 75E-06 | 20 | 100 0 |
| di-n-butylphthalate | 0 003 | n/a | 1 00E+01 | 3 00E-04 | 3 76E-08 | 21 | 100 0 |
| Total risk factor | | | | 7 98E+03 | | | |

**Sources:**
1=Iris
2=Heast 1992
3=Heast 1991
RfDs are in units of mg/kg-day and slope factors are in units of 1/(mg/kg-day)
* cis-1,2-dichloroethene contributes approximately the same amount to the total risk factor as barium and manganese so it is retained as a chemical of concern

# TABLE 3-10

## ROCKY FLATS OU-2
## CONCENTRATION/TOXICTY SCREEN
## NO. 1 SANDSTONE GROUNDWATER
## CARCINOGENS
## (Organics and Metals)

| Chemical | Maximum Value(ppm) | Inhalation Slope Factor | Oral Slope Factor | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| trichloroethene (2) | 94 | 5 95E-03 | 1 10E-02 | 1 03E+00 | 4 32E-01 | 1 | 43 2 |
| tetrachloroethene (2) | 13 | 1 80E-03 | 5 10E-02 | 6 63E-01 | 2 77E-01 | 2 | 70 9 |
| carbon tetrachloride (1) | 4 5 | 5 25E-02 | 1 30E-01 | 5 85E-01 | 2 44E-01 | 3 | 95 3 |
| chloroform (1) | 1 1 | 8 00E-02 | 6 10E-03 | 8 80E-02 | 3 68E-02 | 4 | 99 0 |
| 1,1-dichloroethene (1) | 0 036 | 1 75E-01 | 6 00E-01 | 2 16E-02 | 9 03E-03 | 5 | 99 9 |
| bromodichloromethane (1) | 0 018 | n/a | 6 20E-02 | 1 12E-03 | 4 66E-04 | 6 | 100 0 |
| methylene chloride (1) | 0 04 | 1 60E-03 | 7 50E-03 | 3 00E-04 | 1 25E-04 | 7 | 100 0 |
| bis(2-ethylhexyl)phthalate (1) | 0 017 | n/a | 1 40E-02 | 2 38E-04 | 9 94E-05 | 8 | 100 0 |
| 1,1,1,2-tetrachloroethane (1) | 0 0026 | 2 60E-02 | 2 60E-02 | 6 76E-05 | 2 82E-05 | 9 | 100 0 |
| benzene (2,1) | 0 001 | 2 90E-02 | 2 90E-02 | 2 90E-05 | 1 21E-05 | 10 | 100 0 |
| Total risk factor | | | | 2 39E+00 | | | |

Sources
1=Iris
2=Heast 1991
RFDs are in units of mg/kg-day and slope factors are in units of 1/(mg/kg-day)

## TABLE 3-11

## ROCKY FLATS OU-2
## CONCENTRATION/TOXICITY SCREEN
## NO. 1 SANDSTONE GROUNDWATER
## RADIONUCLIDES
## (Total)

| Chemical | Maximum Value(pCi/L) | Inhalation Slope Factor | Oral Slope Factor | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| plutonium-239,240 (1) | 5 02 | n/a | 2 30E-10 | 1 15E-09 | 8 15E-01 | 1 | 81 5 |
| americium-241 (1) | 1 09 | n/a | 2 40E-10 | 2 62E-10 | 1 85E-01 | 2 | 100 0 |
| Total risk factor | | | | 1 42E-09 | | | |

Sources
1=Heast 1992
Slope factors are in units of 1/pCi

# TABLE 3-12

## ROCKY FLATS OU-2
## CONCENTRATION/TOXICITY SCREEN
## UHSU GROUNDWATER
## NONCARCINOGENS
## (Organics and Dissolved Metals)

| Chemical | Maximum Value | Inhalation RFD | Oral RFD | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| carbon tetrachloride (1) | 17 | n/a | 7 00E-04 | 2 43E+04 | 9 31E-01 | 1 | 93 1 |
| tetrachloroethene (1) | 14 | n/a | 1 00E-02 | 1 40E+03 | 5 37E-02 | 2 | 98 4 |
| chloroform (1) | 1 7 | n/a | 1 00E-02 | 1 70E+02 | 6 52E-03 | 3 | 99 1 |
| *cis-1,2-dichloroethene (2) | 1 4 | n/a | 1 00E-02 | 1 40E+02 | 5 37E-03 | 4 | 99 6 |
| manganese (3) | 3 9 | n/a | 1 00E-01 | 3 90E+01 | 1 49E-03 | 5 | 99 8 |
| 1,1-dichloroethene (1) | 0 26 | n/a | 9 00E-03 | 2 89E+01 | 1 11E-03 | 6 | 99 9 |
| barium (1) | 0 68 | n/a | 7 00E-02 | 9 71E+00 | 3 72E-04 | 7 | 99 9 |
| 1,1,1-trichloroethane (2) | 0 54 | 3 00E-01 | 9 00E-02 | 6 00E+00 | 2 30E-04 | 8 | 100 0 |
| zinc (2) | 0 76 | n/a | 2 00E-01 | 3 80E+00 | 1 46E-04 | 9 | 100 0 |
| naphthalene (2) | 0 09 | n/a | 4 00E-02 | 2 25E+00 | 8 62E-05 | 10 | 100 0 |
| 1,1-dichloroethane (2,3) | 0 19 | 1 40E-01 | 1 00E-01 | 1 90E+00 | 7 28E-05 | 11 | 100 0 |
| trans-1,2-dichlorethene(1) | 0 03 | n/a | 2 00E-02 | 1 50E+00 | 5 75E-05 | 12 | 100 0 |
| bromodichloromethane (1) | 0 02 | n/a | 2 00E-02 | 1 00E+00 | 3 83E-05 | 13 | 100 0 |
| bis(2-ethylhexyl)phthalate (1) | 0 017 | n/a | 2 00E-02 | 8 50E-01 | 3 26E-05 | 14 | 100 0 |
| methylene chloride (2,1) | 0 04 | 9 00E-01 | 6 00E-02 | 6 67E-01 | 2 56E-05 | 15 | 100 0 |
| diethyl phthalate (1) | 0 31 | n/a | 8 00E-01 | 3 88E-01 | 1 49E-05 | 16 | 100 0 |
| toluene (1) | 0 01 | 1 10E-01 | 2 00E-01 | 9 09E-02 | 3 48E-06 | 17 | 100 0 |
| Total risk Factor | | | | 2 61E+04 | | | |

Sources
1=Iris
2=Heast 1992
3=Heast 1991
RfDs are in units of mg/kg-day and slope factors are in units of 1(mg/kg-day)
* Cis-1,2-dichloroethene contributes approximately the same amount to the total risk factor as chloroform, so it is retained as a chemical of concern

## TABLE 3-13

## ROCKY FLATS OU-2
## CONCENTRATION/TOXICITY SCREEN
## UHSU GROUNDWATER
## CARCINOGENS
## (Organics and Total Dissolved Metals)

| Chemical | Maximum Value (ppm) | Inhalation Slope Factor | Oral Slope Factor | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| trichloroethene (2) | 94 | 5 95E-03 | 1 10E-02 | 1 03E+00 | 4 14E-01 | 1 | 41 4 |
| tetrachloroethene (2) | 13 | 1 80E-03 | 5 10E-02 | 6 63E-01 | 2 65E-01 | 2 | 67 9 |
| carbon tetrachloride (1) | 4 5 | 5 25E-02 | 1 30E-01 | 5 85E-01 | 2 34E-01 | 3 | 91 4 |
| 1,1-dichloroethene (1) | 0 2 | 1 75E-01 | 6 00E-01 | 1 20E-01 | 4 80E-02 | 4 | 96 2 |
| chloroform (1) | 1 1 | 8 00E-02 | 6 10E-03 | 8 80E-02 | 3 52E-02 | 5 | 99 7 |
| bromodichloromethane (1) | 0 1 | n/a | 6 20E-02 | 6 20E-03 | 2 48E-03 | 6 | 99 9 |
| 1,1,1,2-tetrachloroethane (1) | 0 05 | 2 60E-02 | 2 60E-02 | 1 30E-03 | 5 20E-04 | 7 | 100 0 |
| methylene chloride (1) | 0 04 | 1 60E-03 | 7 50E-03 | 3 00E-04 | 1 20E-04 | 8 | 100 0 |
| bis(2-ethylhexyl)phthalate (1) | 0 017 | n/a | 1 40E-02 | 2 38E-04 | 9 53E-05 | 9 | 100 0 |
| Total risk factor | | | | 2 50E+00 | | | |

Sources
1=Iris
2=Heast 1991
RfDs are in units of mg/kg-day and slope factors are in units of 1/(mg/kg-day)

## TABLE 3-14

## ROCKY FLATS OU-2
## CONCENTRATION/TOXICITY SCREEN
## UHSU GROUNDWATER
## RADIONUCLIDES (Dissolved)

| Chemical | Maximum Value (pCi/L) | Inhalation Slope Factor | Oral Slope Factor | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| americium-241(1) | 21 3 | n/a | 2 40E-10 | 5 11E-09 | 7 32E-01 | 1 | 73 2 |
| uranium-238 | 76 | n/a | 2 10E-11 | 1 60E-09 | 2 28E-01 | 2 | 96 0 |
| plutonium-239/240(1) | 0 8 | n/a | 2 30E-10 | 1 84E-10 | 2 63E-02 | 3 | 98 6 |
| tritium | 1753 | n/a | 5 40E-14 | 9 47E-11 | 1 35E-02 | 4 | 100 0 |
| Total Risk Factor | | | | 6 99E-09 | | | |

Sources
1=Heast 1992

Slope factors are in units of 1/pCi

## TABLE 3-15

## ROCKY FLATS PLANT OU-2
## CHEMICALS OF CONCERN
## NO. 1 SANDSTONE GROUNDWATER

| Organic Compounds and Metals | Radionuclides |
|---|---|
| carbon tetrachloride | americium-241 |
| chloroform | plutonium-239/240 |
| cis-1,2-dichloroethene | |
| 1,1-dichloroethene | |
| tetrachloroethene | |
| trichloroethene | |
| manganese | |
| barium | |

**TABLE 3-16**

**ROCKY FLATS PLANT OU-2**
**CHEMICALS OF CONCERN**
**UHSU GROUNDWATER**

| Organic Compounds | Radionuclides |
|---|---|
| carbon tetrachloride | americum-241 |
| chloroform | uranium-238 |
| cis-1,2-dichloroethene | plutonium 239/240 |
| 1,1-dichloroethene | tritium |
| tetrachloroethene | |
| trichloroethene | |

**SPECIAL CASE CHEMICALS OF CONCERN**

| |
|---|
| 1,2-dibromoethane |
| vinyl chloride |

**TABLE 3-17**

**ROCKY FLATS PLANT OU-2**
**POTENTIAL CONTAMINANTS WITHOUT EPA TOXICITY FACTORS**
**GROUNDWATER**

| |
|---|
| 1,1-Dichloropropene |
| 1,2,4-Trichlorobenzene |
| 1,2,4-Trimethylbenzene |
| 1,3,5-Trimethylbenzene |
| 1,3-Dichlorobenzene |
| 2-Hexanone |
| Bromochloromethane |
| n-Butylbenzene |
| n-Propylbenzene |
| p-Phlorotoluene |
| p-Cymene |
| Phenanthrene |
| sec-Butylbenzene |
| sec-Dichloropropane |
| Tetrabutylbenzene |

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000781

Titled: OU-2 Monitoring Well Locations Historical, Phase II, and other Investigations

Fiche location: A-OU02-M1

## 4.0
## SUBSURFACE SOIL CHEMICALS OF CONCERN

### 4.1 DATA EVALUATION

Chemicals of concern in subsurface soil were selected using the data set identified in Table 2-2 This includes borehole samples collected in 1987 under the OU-2 Phase I investigation and in 1991-1992 under the OU-2 Phase II investigation Borehole samples were analyzed for volatiles, semivolatiles, pesticides, metals, and radionuclides Borehole locations are shown in Figure 4-1

The data received from RFEDs were reviewed and edited using the steps and criteria outlined in Section 2 1 to develop a data set for further evaluation The data set used to identify potential chemicals of concern for exposure to subsurface soils was restricted to samples collected above the water table so as to avoid the possibility of collecting soil samples that may be cross-contaminated by groundwater

Several common laboratory contaminants detected in subsurface soil samples (bis(2-ethylhexyl)phthalate, di-n-butylphthalate, methylene chloride, and acetone) were evaluated to judge whether their occurrence may be due to cross-contamination from sampling or analytical procedures If these compounds are found in consistently low concentrations regardless of sampling location, it is probable that they are not related to waste sources in OU-2 and can be eliminated from further consideration as chemicals of concern The evaluation of these compounds follows

<u>Bis(2-ethylhexyl)phthalate and di-n-butylphthalate</u> Bis(2-ethylhexyl)phthalate (BEHP) was detected in 47 percent of the subsurface soil samples, and di-n-butylphthalate (DNBP) was detected in only 10 percent of the samples Although in many cases the concentrations were estimated values below the detection limit (330 $\mu g/kg$), in many other cases, elevated concentrations of BEHP ranging from 400 to 12,000 $\mu g/kg$ were detected in spatially related sampling locations, suggesting that BEHP may be an environmental contaminant in these areas For example, BEHP was consistently detected in a series of borings in the Mound Area (borings 3287, 3287, 3387, 3487, 3587, 3687, 3787, and 3887) DNBP was also detected in a number of these borings, but in much lower concentrations (40 to 100 $\mu g/kg$)

BEHP was consistently detected in three borings in the Northeast Trenches Area boring 10191 in Trench T-3 (5500 $\mu g/kg$), boring 4387 in Trench T-4 (360 and 420 $\mu g/kg$), and boring 4587

(770 and 880 $\mu g/kg$) BEHP was also consistently detected in several borings in and south of the 903 Pad, in concentrations ranging from 540 to 1600 $\mu g/kg$.

The 1987 borehole data have not been validated Therefore, it is not known whether the BEHP and DNBP detected in these samples result from field or laboratory contamination Because of this uncertainty, BEHP and DNBP are considered to be possible OU-2 contaminants in subsurface soil and are included in concentration/toxicity screens for this medium

Methylene Chloride Methylene chloride was detected in about 30 percent of the subsurface soil samples Detected concentrations range from 1 $\mu g/kg$ to 37 $\mu g/kg$ About two-thirds of the results were B or J qualified (typical reporting limit was 5 $\mu g/kg$, some samples with positive results had reporting limits of 25 $\mu g/kg$)

At these low concentrations, methylene chloride is not of particular concern for adverse health effects, and its presence may or may not be due to environmental contamination in OU-2 Nevertheless, it is included in the concentration/toxicity screens to identify chemicals of concern for subsurface soils Based on the screens (Tables 4-5 and 4-6) methylene chloride is not a chemical of concern in soils in OU-2

Acetone Concentrations of acetone ranging from 3 to 340 $\mu g/kg$ (and one J-qualified result of 26,000 $\mu g/kg$) were observed in subsurface soil samples collected in the Northeast Trenches Area Acetone was detected in concentrations ranging from 19 to 500 $\mu g/kg$ (reporting limit = 25 $\mu g/kg$) in numerous subsurface soil samples in the Mound Area However, most of these samples did not have detected concentrations of other VOCs, and, therefore, acetone is considered to be a probable laboratory contaminant in these samples

Historical information indicates that acetone still bottoms were located in the 903 Pad Area However, acetone was detected in only a few samples taken from this area at concentrations at less than 50 $\mu g/kg$ Therefore, it is unlikely that acetone is an environmental contaminant in the 903 Pad

In conclusion, acetone appears to be a minor contaminant, and may be a result of laboratory contamination For example, it is detected in a number of samples where no other VOCs are detected, this suggests the possibility of laboratory contamination In some areas (e g, Southeast Trenches and Mound Area) it is detected in fairly consistent concentrations regardless of depth (data not shown) This pattern is not indicative of a concentration gradient resulting from chemical releases The single high detection of 26,000 $\mu g/kg$ (reporting limit = 25,000 was in a sample that was diluted 5000 times because of high concentrations of chlorinated solvents The acetone reported in this sample could be due to laboratory contamination (although the result was not B qualified)

Even though it is uncertain whether acetone is a site-related contaminant in OU-2, it is included in the concentration/toxicity screen for noncarcinogenic effects at its maximum reported concentration of 26,000 μg/kg This is a highly conservative approach, because this concentration is not characteristic of subsurface soils Based on the results of the concentration/toxicity screen, acetone is not a chemical of concern in subsurface soils in OU-2

## 4.2 BACKGROUND COMPARISON FOR INORGANIC COMPOUNDS

Tables 4-1 and 4-2 summarize the results of comparing concentrations of metals and radionuclides in borehole samples to background levels Metals and radionuclides that did not exceed background levels were eliminated from further consideration as potential chemicals of concern The background comparison process is described in Appendix A

### 4.2.1. Metals

On the basis of the statistical tests, the following metals do not appear to exceed background levels (i e , the metal did not exceed background by using both the UTL and ANOVA tests) aluminum, barium, beryllium, chromium, cobalt, copper, lead, lithium, manganese, nickel, selenium, silver, tin, vanadium, and zinc Only antimony, arsenic, cadmium, cesium, mercury, molybdenum, strontium, and thallium appear to exceed background by one or both tests Of these, arsenic, cadmium, and strontium are retained as probable OU-2 contaminants and are included in concentration/toxicity screens to identify chemicals of concern The reasons for retaining these metals are outlined below

Metals Retained as Potential Contaminants
on the Basis of Data Evaluation
Subsurface Soils

Arsenic Arsenic is retained as a contaminant because it was detected in 47 subsurface soil samples above the background UTL of 12 mg/kg (Background maximum = 42 mg/kg, all but two background sample results were at or below 11 mg/kg ) Concentrations of arsenic in OU-2 samples above the UTL ranged from 12 to 37 mg/kg The maximum concentration was detected ın BH3987 (Northeast Trenches Area) at a depth of 0 to 2 feet and 25 mg/kg at 14 5 to 17 feet

Elevated concentratıons of arsenıc were detected wıthın three source boreholes ın Trench T-7 (IHSS 111 4) ın the Southeast Trenches Area An arsenıc concentratıon of 22 8 mg/kg was detected from a depth of 6 to 7 4 feet ın BH4887, 25 7 mg/kg was detected from a depth of 7 to 8 9 feet ın BH5087, and 29 6 mg/kg was detected from a depth of 6 to 7 5 feet ın BH5487 Addıtıonally, an arsenıc concentratıon of 28 4 mg/kg was detected ın BH5187 at a depth of 0 to 9 feet BH5187 ıs located ın Trench T-8 (IHSS 111 5)

Although arsenıc ıs a naturally occurrıng element ın soıls, the frequency of detectıon above background levels precludes the exclusıon of arsenıc as a potentıal OU-2 contamınant ın subsurface soıls

Cadmıum Cadmıum was detected ın 36 percent of the subsurface soıl samples ın concentratıons exceedıng the background UTL of 2 mg/kg Concentratıons above background UTL range from 2 1 to 10 mg/kg The maxımum concentratıon of cadmıum was detected ın source borehole 10291 from a depth of 2 to 8 feet Borehole 10241 located ın Trench T-4 (IHSS 111 1) wıthın the Northeast Trenches Area Other boreholes ın the Northeast Trenches Area had concentratıons of cadmıum rangıng from 2 1 to 5 6 mg/kg, in samples obtaıned from a depth of less then 10 feet (the approxımate maxımum depth of a trench) Samples from BH2587 and BH2787 had cadmıum concentratıons of 5 2 and 5 4 mg/kg respectıvely at a depth of less than 10 feet Although cadmıum concentratıons ın OU-2 were not substantıally above the background UTL, the relatıvely hıgh frequency of detectıon above the UTL and the occurrence ın known dısposal trenches preclude the exclusıon of cadmium as a potentıal OU-2 contamınant

Strontıum Strontıum was detected ın 12 subsurface soıl samples above the background UTL of 127 mg/kg Concentratıons of strontıum above the background UTL ranged from 133 to 246 mg/kg The maxımum concentratıon was detected ın borehole 319787 from a depth of 0 to 3 feet Eıght of the 12 strontıum detectıons above background were obtaıned from boreholes ın the Southeast Trenches Area from a depth of less than 10 feet (the approxımate maxımum depth of a trench) Two strontıum detectıons were obtaıned from boreholes located beneath the 903 Pad (IHSS 112) and the other two detectıons were located ın the Mound Area (IHSS 113) All elevated results were ın samples collected from a depth of less than 10 feet

Although strontium did not have a high frequency of detection, it was detected in several samples at concentrations above the background UTL in known disposal trenches Therefore, strontium is considered a potential OU-2 contaminant in subsurface soils

Metals Eliminated as Contaminants
on the Basis of Data Evaluation
Subsurface Soils

Antimony, cesium, mercury, molybdenum, and thallium exceeded background by one statistical test but not by another These metals are eliminated from further consideration for the reasons outlined below

Antimony Antimony was detected at concentrations above the background UTL of 12 mg/kg in only two subsurface soil samples collected in the 903 Pad area Detected concentrations were 16 and 24 mg/kg Background maximum was 16 mg/kg, with a detection frequency of 16 percent Based on the overall low frequency of detection (4 percent), the fact that only two results exceeded the background UTL, and that antimony did not exceed background by the ANOVA test, antimony is not considered an OU-2 contaminant in subsurface soils

Cesium Cesium is eliminated from further consideration because it is below background by the ANOVA test, and the results that exceeded the background UTL were non-detect (one-half reporting limits)

Mercury Mercury was detected in about 20 percent of the samples analyzed, in concentrations ranging from 0 06 to 0 49 mg/kg (detection limit = 0 1 mg/kg), with one elevated concentration of 114 mg/kg detected in a 0 to 10-foot composite sample from borehole 2987 This borehole is located west of the 903 Pad and is unrelated to known source areas Background UTL is 1 mg/kg and the background maximum is 6 mg/kg Because all OU-2 results are below the background UTL, except for the one outlier at a location unrelated to known source areas, mercury is not considered a contaminant in OU-2

Molybdenum Molybdenum is eliminated from further consideration because it is below background by the ANOVA test and the results that exceeded the background UTL were non-detect (one-half reporting limits)

Thallium Thallium is eliminated from further consideration as a contaminant in subsurface soils because all of the results were below the background UTL of 3 mg/kg and the OU-2 mean concentration of 1 mg/kg is comparable to the background mean of 0 8 mg/kg

### 4.2.2 Radionuclides

Table 4-2 summarizes the background comparison radionuclides in subsurface soils For a number of the analytes, few background data were available for comparison Radium-226, strontium-89,90 and strontium 90 did not exceed background based on both statistical comparisons and were eliminated from further consideration on that basis Americium-241, plutonium-239,240, and cesium-137 are probable contaminants based on the percentage of results (33% to 78%) that exceed the background UTLs Nearly all elevated tritium results (17 samples) occurred in trenches in the Southeast Trenches Area or at the 903 Pad, therefore, tritium is retained as a probable contaminant in subsurface soils Although only a small percentage (3%) of results for uranium-238 exceeded the background UTL (1 5 pCi/g), the elevated concentrations ranged from 2 to 133 pCi/g and were detected in the 903 Pad Area and at Trenches T-3 and T-4 in the Northeast Trenches Area, therefore, uranium-238 is retained as a probable contaminant in OU-2 For the reasons outlined below, uranium 233/234 and uranium 235 were retained as "special case" contaminants, and radium-228 was eliminated from further consideration

Uranium-233,234 Uranium-233,234 was detected in two borehole samples (1 percent) above the background UTL of 2 5 pCi/g Concentrations above background UTL ranged from 14 35 to 191 7 pCi/g The maximum concentration was obtained from borehole 10291 from a depth of 2 to 8 feet Source borehole 10291 is located in Trench T-4 (IHSS 111 1) Borehole 10191, which is located in Trench T-3 (IHSS 111 0), had a concentration of 14 35 pCi/g from a depth of 4 2 to 8 0 feet Review of the data indicates that uranium-233,234 is not a contaminant characteristic of OU-2 soils However, it is a local contaminant in Trenches T-3 and T-4 and is retained as a "special case" chemical of concern for evaluation in the risk assessment

Uranium-235 Uranium-235 was also detected in two borehole samples above the background UTL of 0 2 pCi/g Uranium-235 concentrations in boreholes 10191 and 10291 were 0 75 pCi/g and 11 5 pCi/g, respectively Both detections were from the uppermost composite sample Due to the low frequency of elevated concentrations, it is not considered a contaminant characteristic of subsurface soils in OU-2 However, uranium-235 is a local contaminant in Trenches T-3 and T-4 and is retained as a "special case" chemical of concern for evaluation in the risk assessment

Radium-228 Radium-228 was detected in six borehole samples (9 percent) above the background UTL of 2 0 pCi/g Concentrations above background UTL range from 2 044 to 2 6 pCi/g Because the maximum concentration (2 6 pCi/g) is not substantially higher than the background UTL (2 0 pCi/g) or the background maximum (2 2 pCi/g), radium-228 is not considered a contaminant in subsurface soil in OU-2

## 4.3 FREQUENCY OF DETECTION

Organic compounds detected at a frequency of 5 percent or greater were considered potential chemicals of concern and are listed in Table 4-3 These compounds are included in the concentration/toxicity screens for subsurface soils (Section 4 4)

Compounds detected in subsurface soils at less than 5 percent frequency are listed in Table 4-4 The potential for exposure to infrequently detected compounds is low Nevertheless, concentrations of infrequently detected organic compounds were further evaluated as described in Section 4 5 to identify those that could contribute significantly to risk if exposure were to occur

## 4.4 CONCENTRATION/TOXICITY SCREENS

Concentration/toxicity screens were used to identify chemicals, based on concentration and toxicity, that could contribute significantly to risk and to eliminate chemicals from quantitative evaluation in the risk assessment that contribute insignificantly to risk The screen was performed on chemicals detected above background and at a frequency of 5 percent or greater The concentration/toxicity screen process was explained in Section 2 4 Results of the screen for borehole data are shown in Tables 4-5 (Noncarcinogenic Effects), 4-6 (Carcinogenic Effects), and 4-7 (Radionuclides) Chemicals of concern are summarized in Table 4-8 All chemicals that comprise approximately 99 percent of the total risk factor are identified as chemicals of concern to be evaluated in the risk assessment

Compounds without EPA-established toxicity factors cannot be assessed and are not included in the concentration/toxicity screen Table 4-9 identifies the compounds for which EPA has not established toxicity factors These compounds will be addressed qualitatively in the risk assessment

## 4.5 EVALUATION OF INFREQUENTLY DETECTED COMPOUNDS

Compounds detected at less than 5 percent frequency may be eliminated from further consideration because the potential for exposure is low However, these compounds were further screened so as not to neglect infrequently detected compounds that could contribute significantly to risk if exposure were to occur In this screen, maximum concentrations of infrequently detected compounds were compared to risk-based screening values using the approach outlined in Section 2 5 and described in greater detail in Appendix B

Results of the comparison are shown in Tables B-7 and B-8 No infrequently detected compounds in subsurface soils were present at concentrations greater than the screening values used in the analysis

## 4.6 SUMMARY OF CHEMICALS OF CONCERN IN SUBSURFACE SOIL

OU-2 chemicals of concern in subsurface soil identified by the approach described above are listed in Table 4-8 These are arsenic, cadmium, tetrachloroethene, uranium-238, americium-241, and plutonium-239/240 Special case chemicals of concern are uranium-233,234 and uranium-235, based on the occurrence of elevated concentrations in two samples from the Northeast Trenches Area

**TABLE 4-1**
**ROCKY FLATS PLANT OU-2**
**SUMMARY OF BACKGROUND COMPARISON**
**METALS IN SUBSURFACE SOIL, mg/kg**

| Analyte | DF % (1) | % Data > 95% UTL (1) | ANOVA p (2) | Potential Contaminant? No (3) | Potential Contaminant? Yes (4) | Spatial/Temporal/Other (see text) | OU-2 Contaminant? |
|---|---|---|---|---|---|---|---|
| Aluminum | 100 | 0 | 0 63 | x | | | No |
| Antimony | 4 | 5 | 0 43 | | ? | 4% DF, 2 results > bknd UTL | No |
| Arsenic | 94 | 11 | <0 01 | | x | | Yes |
| Barium | 83 | 2 | <0 01* | x | | | No |
| Beryllium | 47 | 0 4 | <0 01* | x | | | No |
| Cadmium | 45 | 36 | 0 01* | | x | | Yes |
| Cesium | 91 | 7 | <0 01* | | ? | Results > bknd UTL are non-detect (half det. limit) | No |
| Chromium | 98 | 1 | <0 01* | x | | | No |
| Cobalt | 55 | 2 | <0 01* | x | | | No |
| Copper | 84 | 1 | <0 01* | x | | | No |
| Lead | 99 | 1 | <0 01* | x | | | No |
| Lithium | 91 | 1 | 0 91 | x | | | No |
| Manganese | 100 | 1 | 0 91 | x | | | No |
| Mercury | 20 | 1 | <0 01 | | ? | 3 hits above background UTL | No |
| Molybdenum | 33 | 7 | 0 75 | | ? | Results >UTL are non-detect (reporting limits) | No |
| Nickel | 79 | 0 4 | <0 01* | x | | | No |
| Selenium | 7 | 0 | <0 01* | x | | | No |
| Silver | 13 | 1 | <0 01* | x | | | No |
| Strontium | 82 | 5 | <0 01* | | ? | Probable contaminant in source areas | Yes |
| Thallium | 12 | 0 | <0 01 | | ? | OU2 Max = 1, bknd UTL = 3 | No |
| Tin | 24 | 0 | 0 31 | x | | | No |
| Vanadium | 97 | 0 | 0 03* | x | | | No |
| Zinc | 98 | 2 | <0 01* | x | | | No |

(1) Detection frequency and UTL comparison from Table A-5
(2) Table A-13 p < 0 05 is considered significant.
(3) <5% data exceeds 95% UTL and p > 0 05
* Background mean is equal to or exceeds OU2 mean

(4) > 5% data exceeds 95% UTL and p < 0 05
? Either >5% data exceeds 95% UTL or p < 0 05

**TABLE 4-2**

**ROCKY FLATS PLANT OU-2**
**SUMMARY OF BACKGROUND COMPARISON**
**RADIONUCLIDES IN SUBSURFACE SOIL, pCi/g**
**VADOSE ZONE**

| Analyte | DF % (1) | % Data > 95% UTL (1) | ANOVA p (2) | Potential Contaminant? No (3) | Potential Contaminant? Yes (4) | Spatial/Temporal/Other (see text) | Retain for Further Evaluation? |
|---|---|---|---|---|---|---|---|
| Americium 241 | 83 | 77 | 0 06 | | X | Probable contaminant | Yes |
| Cesium 137 | 66 | 33 | 0 89 | | X | Possible contaminant | Yes |
| Plutonium 239 | 78 | - | <0 01 | | X | | Yes |
| Radium 226 | 90 | 3 | <0 01* | X | | | No |
| Radium 228 | 100 | 9 | 0 94 | | ? | OU2 Max = 2 6 pCi/g; bknd UTL = 2 0 pCi/g | No |
| Strontium 89,90 | 73 | 0 | <0 01* | X | | OU-2 mean <bknd mean | No |
| Strontium 90 | 100 | - | - | X | | Max = bknd UTL for Sr-89-90 | No |
| Tritium (pCi/L) | 74 | 7 | <0 01* | | X | Contaminant at 903 Pad and SE Trenches | Yes |
| Uranium 233,234 | 100 | 1 | <0 01 | | ? | 2 results >bknd UTL at Trenches T-3, T-4 | Special Case |
| Uranium 235 | 88 | 2 | <0 01* | | ? | 2 results >bknd UTL at Trenches T-3, T-4 | Special Case |
| Uranium 238 | 100 | 3 | <0 01 | | ? | t at 903 Pad and Trenches T-3, T-4 | Yes |

(1) Detection frequency and UTL comparison from Table A-6
(2) Table A-14 p < 0 05 is considered significant.
(3) <5% data exceeds 95% UTL and p > 0 05
(4) > 5% data exceeds 95% UTL and p <0 05
? Either > 5% data exceeds 95% UTL or p <0 05
* Background mean is equal to or exceeds OU2 mean
\- Statistical test could not be made

**TABLE 4-3**
**ROCKY FLATS PLANT OU-2**
**ORGANIC COMPOUNDS DETECTED AT**
**5% or GREATER FREQUENCY**
**SUBSURFACE SOIL**

| | Maximum Concentration, mg/kg | Detection Frequency % |
|---|---|---|
| Acetone | 26 | 34 |
| Methylene chloride | 037 | 32 |
| 1,2-Dichloroethane | 0 120 | 12 |
| 2-Butanone | 0 15 | 7 |
| 1,1,1-Trichloroethane | 13 | 7 |
| Trichloroethene | 120 | 5 3 |
| Toluene | 1 1 | 34 |
| Tetrachloroethene | 13000 | 11 |
| Total xylenes | 0 23 | 5 |
| Bis(2-ethylhexyl)phthalate | 12 | 47 |
| N-Nitrosodiphenylamine | 0 37 | 18 |
| Di-n-butyl phthalate | 3 4 | 10 |

## TABLE 4-4
## ROCKY FLATS PLANT OU-2
## ORGANIC COMPOUNDS DETECTED AT LESS THAN 5% FREQUENCY
## SUBSURFACE SOIL

| | Maximum Concentration mg/kg | Detection Frequency % |
|---|---|---|
| 1,1,2-Trichloroethane | 0.027 | 0.7 |
| 1,1-Dichloroethane | 0.008 | 0.3 |
| 1,2-Dichloroethane | 0.09 | 2 |
| 2-Chloroethylvinylether | 0.031 | 0.7 |
| Benzene | 0.012 | 0.3 |
| Bromomethane | 0.006 | 0.3 |
| Carbon tetrachloride | 140 | 4 |
| Chloroethane | 0.050 | 0.3 |
| Chloroform | 8.8 | 3 |
| Cis-1,3-dichloropropene | 0.006 | 0.3 |
| Ethylbenzene | 0.78 | 1 |
| Styrene | 0.17 | 0.3 |
| Aroclor-1254 | 8.9 | 2 |
| 4,4'-DDT | 0.14 | 0.35 |
| Pentachlorophenol | 0.095 | 0.7 |
| 1,4-Dichlorobenzene | 0.043 | 0.4 |
| Fluoranthene | 1.0 | 1.8 |
| Pyrene | 1.3 | 2.2 |
| Di-n-octyl phthalate | 0.26 | 0.4 |
| Phenanthrene | 2.7 | 1.8 |
| 2-Methylnaphthalene | 8.1 | 1 |
| Acenaphthene | 0.28 | 0.7 |
| Benzo(a)pyrene | 0.48 | 0.7 |
| Chrysene | 0.42 | 0.7 |
| Naphthalene | 2.0 | 0.7 |
| Benzoic Acid | 0.4 | 0.4 |

## TABLE 4-5

## ROCKY FLATS PLANT OU-2
## CONCENTRATION/TOXICITY SCREEN
## SUBSURFACE SOIL
## NONCARCINOGENS
## (Organics and Metals)

| Chemical | Maximum Value (ppm) | Inhalation RFD | Oral RFD | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| tetrachloroethene(1) | 13000 | n/a | 1 00E-02 | 1 30E+06 | 9 06E-01 | 1 | 90 6 |
| arsenic(1) | 37 | n/a | 3 00E-04 | 1 23E+05 | 8 59E-02 | 2 | 99 2 |
| cadmium (1) | 10 5 | n/a | 1 00E-03 | 1 05E+04 | 7 32E-03 | 3 | 99 9 |
| bis(2-ethylhexyl)phthalate | 12 | n/a | 2 00E-02 | 6 00E+02 | 4 18E-04 | 4 | 100 0 |
| strontium (2) | 246 | n/a | 8 80E-01 | 2 80E+02 | 1 95E-04 | 5 | 100 0 |
| acetone (1) | 26 | n/a | 1 00E-01 | 2 60E+02 | 1 81E-04 | 6 | 100 0 |
| 1,1,1-trichlorethane(2) | 13 | 3 00E-01 | 9 00E-02 | 1 44E+02 | 1 01E-04 | 7 | 100 0 |
| toluene(1) | 1 4 | 1 10E-01 | 2 00E-01 | 1 27E+01 | 8 87E-06 | 8 | 100 0 |
| 2-butanone(1) | 0 21 | 3 00E-01 | 6 00E-01 | 7 00E-01 | 4 88E-07 | 9 | 100 0 |
| methylene chloride (1) | 0 037 | 9 00E-01 | 6 00E-02 | 6 17E-01 | 4 30E-07 | 10 | 100 0 |
| di-n-butylphthalate | 3 4 | n/a | 1 00E+01 | 3 40E-01 | 2 37E-07 | 11 | 100 0 |
| total xylenes(1) | 0 23 | n/a | 2 00E+00 | 1 15E-01 | 8 01E-08 | 12 | 100 0 |
| Total Risk Factor | | | | 1 44E+06 | | | |

Sources
(1) Iris
(2) Heast 1992
Toxicity factors are in units of mg/kg-day (RfDs) and 1/(mg/kg-day) (slope factors)

## TABLE 4-6

### ROCKY FLATS OU-2
### CONCENTRATION/TOXICITY SCREEN
### SUBSURFACE SOIL
### CARCINOGENS
### (Organics and Metals)

| Chemical | Maximum Value (ppm) | Inhalation Slope Factor | Oral Slope Factor | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| tetrachloroethene(2) | 13000 | 1 80E-03 | 5 10E-02 | 6 63E+02 | 5 16E-01 | 1 | 51 6 |
| arsenic(1) | 37 | 1 50E+01 | 1 75E+00 | 5 55E+02 | 4 32E-01 | 2 | 94 7 |
| cadmium (1) | 10 5 | 6 30E+00 | n/a | 6 62E+01 | 5 15E-02 | 3 | 99 9 |
| trichloroethene(2) | 120 | 5 95E-03 | 1 10E-02 | 1 32E+00 | 1 03E-03 | 4 | 100 0 |
| bis(2-ethylhexyl)phthalate(1) | 12 | n/a | 1 40E-02 | 1 68E-01 | 1 31E-04 | 5 | 100 0 |
| 1,2-dichloroethane (1) | 0 12 | 9 10E-02 | 9 10E-02 | 1 09E-02 | 8 49E-06 | 6 | 100 0 |
| N-nitrosodiphenylamine(1) | 0 37 | n/a | 4 90E-03 | 1 81E-03 | 1 41E-06 | 7 | 100 0 |
| methylene chloride (1) | 0 037 | 1 60E-03 | 7 50E-03 | 2 78E-04 | 2 16E-07 | 8 | 100 0 |
| Total risk factor | | | | 1 29E+03 | | | |

Sources
(1) Iris
(2) Heast 1991

Toxicity factors are in units of mg/kg-day (RFDs) and 1/(mg/kg-day) (slope factors)

## TABLE 4-7

## ROCKY FLATS OU-2
## CONCENTRATION/TOXICITY SCREEN
## SUBSURFACE SOIL
## RADIONUCLIDES

| Chemical | Maximum Value (pCi/g) | Inhalation Slope Factor | Oral Slope Factor | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| uranium-238 (1) | 113 | 2 40E-08 | 1 60E-11 | 2 71E-06 | 4 91E-01 | 1 | 49 1 |
| plutonium-239/240(1) | 68 | 3 80E-08 | 2 30E-10 | 2 58E-06 | 4 68E-01 | 2 | 95 8 |
| americium-241(1) | 7 | 3 20E-08 | 2 40E-10 | 2 30E-07 | 4 17E-02 | 3 | 100 0 |
| tritium (1) (pCi/L) | 1500 | 7 80E-14 | 5 40E-14 | 1 17E-10 | 2 12E-05 | 4 | 100 0 |
| cesium-137(1) | 2 4 | 1 90E-11 | 2 80E-11 | 6 72E-11 | 1 22E-05 | 5 | 100 0 |
| Total Risk Factor | | | | 5 53E-06 | | | |

**Sources**
(1) Heast 1992

Slope factors are in units of 1/pCi

## TABLE 4-8

## ROCKY FLATS PLANT OU-2
## CHEMICALS OF CONCERN
## SUBSURFACE SOIL

| Organic Compounds and Metals | Radionuclides |
|---|---|
| tetrachloroethene | americium 241 |
| arsenic | plutonium 239/240 |
| cadmium | uranium-238 |

## SPECIAL CASE
## CHEMICALS OF CONCERN

| Compound | Location |
|---|---|
| uranium-233,234 | Trenches T-3 and T-4 |
| uranium-235 | Trenches T-3 and T-4 |

## TABLE 4-9

## DETECTED COMPOUNDS WITHOUT EPA TOXICITY FACTORS SUBSURFACE SOIL

| |
|---|
| 2-methylnaphthalene |
| 4-methylphenol |
| benzo(ghi)perylene |

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000781

Titled: OU-2 Borehole Locations Historical, Phase II and other Investigations

Fiche location: A-OU02-M1

## 5.1 DATA EVALUATION

Chemicals of concern in surface soil were selected using the data set identified in Table 2-2 This includes surface soil samples collected in 1991 (radionuclides) and in 1993 Surface soil samples were analyzed for semivolatiles, pesticides, metals, and radionuclides Sampling locations are shown in Figures 5-1 and Figure 5-2

The occurrences of benzoic acid, polycyclic aromatic hydrocarbons (PAHs), and bis(2-ethylhexyl)phthalate detected in surface soil samples were evaluated to judge whether or not their presence is likely to be due to waste releases in OU-2 This evaluation is described below

- Benzoic Acid

  Benzoic acid was detected in 88 percent of the surface soil samples obtained within OU-2 Benzoic acid concentrations were all estimated below the detection limit of 1,600 $\mu$g/kg Benzoic acid results range from about 40 to 700 $\mu$g/kg (most fell between 100 and 300 $\mu$g/kg) and are evenly distributed across OU-2 with no relationship to source areas In addition, benzoic acid was also detected in 58 percent of the background data within the range of 40 to 230 $\mu$g/kg The range of concentrations of benzoic acid in OU-2 is similar to the range of background concentrations The reported results in background and OU-2 samples may be an artifact of the analytical method Therefore, benzoic acid is not considered as a waste-related contaminant in OU-2

- PAHs

  Pyrene, fluoranthene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(a)anthracene, chrysene, and phenanthrene were detected in 17 to 46 percent of 52 surface soil samples obtained within OU-2 These semivolatiles are typical products of hydrocarbon combustion and are associated with vehicle emissions and burning of coal, wood, charcoal, and petroleum-based fuels PAHs were detected in surface soil samples collected around the Pallet Burn Site (IHSS 154) and the Reactive Metal Destruction Site (IHSS 140) at estimated concentrations ranging from 38 to 390 $\mu$g/kg The concentrations of PAHs at these locations are similar to other PAH concentrations observed across OU-2, which ranged from approximately 47 to 390 $\mu g/kg$ Because the PAHs appear to result from vehicle emissions and wood or fuel combustion rather than chemical releases in OU-2 and because concentrations are consistently low, PAHs found in surface soils are not considered to be waste-related contaminants in OU-2

- Bis(2-ethylhexyl)phthalate

Bis(2-ethylhexyl)phthalate was detected in 11 of 52 (21 percent) surface soil samples widely distributed across OU-2, including locations distant from source areas Concentrations in most samples ranged from 49 to 110 $\mu g/kg$ (detection limit = 330 $\mu g/kg$), and one sample had a concentration of 510 $\mu g/kg$ In background samples, bis(2-ethylhexyl)phthalate was detected in 22 percent of the samples in concentrations ranging from 35 to 140 $\mu g/kg$ Since the distribution of OU-2 results and background results are similar, it is concluded that bis(2-ethylhexyl)phthalate in OU-2 samples is not related to waste releases, and it is not considered an OU-2 contaminant

## 5.2 BACKGROUND COMPARISON FOR INORGANIC COMPOUNDS

Tables 5-1 and 5-2 summarize the results of comparing concentrations of metals and radionuclides in OU-2 surface soil samples to background levels Background surface soil data consist of analytical results from samples collected at 18 locations in the Rock Creek area Nine of the sites were sampled in February 1992 and the remaining nine sites were sampled in March 1993 All background samples were collected using the "RFP" method, a composite method in which the top 2 inches of soil are collected The OU-2 samples were collected during three sampling events Samples analyzed for uranium were collected during Summer 1991 by the "CDH" method, a method in which the top 1/4" of soil is collected Samples analyzed for plutonium and americium were collected in Fall 1991 using the RFP method Additional samples for other radionuclides and metals were collected by the RFP method in March 1993 Metals and radionuclides that did not exceed background levels were eliminated from further consideration as potential chemicals of concern The background comparison process is described in Appendix A

### 5.2.1 Metals

Most metals do not exceed background using both statistical tests (UTL and ANOVA, see Table 5-1), and these are not considered further However, beryllium, cadmium, selenium, thallium, and tin appear to exceed background by the ANOVA test Nevertheless, these metals are not considered to be OU-2 contaminants in surface soils for the reasons outlined below Chromium is considered a "special case" chemical of concern, as discussed below

<u>Beryllium.</u> Beryllium was detected in 1 of 40 samples (3 percent detection frequency) at a concentration of 1 3 mg/kg, which is below the background maximum of 2 5 mg/kg, and below the background UTL of 3 56 mg/kg Therefore, beryllium is not considered a contaminant of concern in surface soils in OU-2

<u>Cadmium</u> Cadmium was detected in 5 of 40 samples None of the cadmium results exceeded the background UTL, and the maximum cadmium concentration detected in OU-2 samples (2 2 mg/kg) is below the background maximum (2 5 mg/kg)

<u>Selenium</u> Selenium was detected in 3 of 40 samples Only one selenium result (0 9 mg/kg) exceeded the background UTL of 0 8 mg/kg, and the maximum detected concentration (0 9 mg/kg) is less than the background maximum (1 0 mg/kg) Therefore, selenium is not considered a contaminant in OU-2 surface soil

<u>Thallium</u> Thallium is not considered an OU-2 contaminant because it was detected in only 1 of 40 samples (3 percent detection frequency) at a concentration of 0 5 mg/kg, which is below the background UTL of 1 1 mg/kg and below the background maximum of 1 mg/kg

<u>Tin</u> Tin was detected in 16 of 40 samples In one of the 16 samples it was detected at a concentration of 93 mg/kg, which is above the background UTL of 56 mg/kg This sample was collected near Indiana Street Therefore, tin is not considered a contaminant in OU-2 because the only sample result that exceeded the background UTL was detected at a location unrelated to source areas

<u>Chromium</u> Chromium was detected in two samples at concentrations above the background maximum of 22 mg/kg (background UTL = 23 5 mg/kg) One sample (26 mg/kg) was collected from the Reactive Metal Destruction Site ("Lithium Burn Pit"), and the other (29 5 mg/kg) was collected west (upgradient) of the chromium spray fields Because only two sample results exceeded background range, chromium contamination is not characteristic of surface soils in OU-2 However, chromium is considered a "special case" chemical of concern for separate evaluation in the risk assessment because of the slightly elevated concentrations in two samples potentially related to source areas All other sampling locations had chromium concentrations within background range, and most of the chromium detected in the two samples discussed

above is also likely due to background concentrations in soil (i e , only the fraction exceeding background levels would be due to waste releases)

The chromium detected in the samples is largely chromium III This is the predominant form of chromium in the environment Special analyses for chromium VI (a more oxidized form that is carcinogenic) were performed on samples collected near the chromium spray fields Twelve samples were analyzed for chromium VI The results ranged from 0 9 mg/kg to 1 2 mg/kg, or approximately 5 percent of the total chromium measured in the samples, regardless of sampling location The low percentage of chromium VI compared to chromium III is to be expected in naturally occurring chromium compounds or in chrome-bearing industrial wastes exposed to the environment, where natural processes result in reduction of chromium VI to chromium III

In conclusion, metals other than chromium are not considered contaminants in surface soils in OU-2

### 5.2.2 Radionuclides

The radionuclides cesium 137, radium 228, and strontium 89,90 do not exceed background, based on results of both statistical tests (Table 5-2) The radionuclides americium-241 and plutonium-239 are considered OU-2 contaminants The uranium isotopes (233/234, 238, and 239) are considered further as possible OU-2 contaminants based on spatial evaluation of the data, as described below Radium 226 is not considered an OU-2 contaminant (see below)

<u>Radium 226</u> Radium 226 was detected in all 24 surface soil samples analyzed for radionuclides, but only one sample had a concentration (11 8 mg/kg) that exceeded the background UTL of 1 3 mg/kg This sample was collected in plot 8180 near Indiana Street, distant from OU-2 source areas Because the elevated concentration was found in only one sample distant from OU-2 source areas, radium 226 is not considered an OU-2 contaminant

<u>Uranium isotopes.</u> The uranium isotopes appear to exceed background levels by the UTL comparison (over 20 percent of the data exceeded background UTLs), but population differences between OU-2 data and background were not significant by the ANOVA test ($p < 0\ 05$) Spatial evaluation shows that elevated concentrations of the analytes uranium-233/234, 235, 238, and 233/238/239 occur in an area east of the 903 Pad These are considered OU-2 contaminants and retained for further evaluation as potential chemicals of concern in a concentration/toxicity screen

## 5.3 FREQUENCY OF DETECTION

Of the organic analytes, benzoic acid, bis(2-ethylhexyl)phthalate, and the PAHs benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene were detected in surface soils at a frequency of 5 percent or greater These compounds are listed in Table 5-3 None of these compounds are likely to be related to waste sources in OU-2, as described in Section 5 1, and they are not considered to be OU-2 contaminants

Compounds detected in surface soils at less than 5 percent frequency are listed in Table 5-4 These include benzo(ghi)perylene, benzo(k)fluoranthene, indeno(1,2,3-cd) pyrene, PCBs, DDT, and delta-BHC The potential for exposure to infrequently detected compounds is low Nevertheless, concentrations of these compounds were further evaluated in a risk-based screen as described in Section 5 5

## 5.4 CONCENTRATION/TOXICITY SCREENS

No site-related organic compounds or metals were identified in surface soils with the exception of the infrequently detected organic compounds that are evaluated in Section 5 5 and chromium (a "special case" chemical of concern) Therefore, a concentration/toxicity screen was performed only for radionuclides of potential concern The concentration/toxicity screen process was explained in Section 2 4 Results of the screen for radionuclides in surface soil are shown in Table 5-5 Plutonium-239/240 contributes over 98 percent of the total risk factor Americium-241 contributes approximately 1 percent of the total risk factor The uranium isotopes contribute insignificantly to the total risk factor and are eliminated as chemicals of concern in surface soils Table 5-6 summarizes the chemicals of concern in surface soils. All chemicals that comprise approximately 99 percent of the total risk factor are identified as chemicals of concern to be evaluated in the risk assessment

## 5.5 EVALUATION OF INFREQUENTLY DETECTED COMPOUNDS

Compounds detected at less than 5 percent frequency may be eliminated from further consideration because they are not characteristic of contamination and because the potential for exposure is low However, these compounds were further screened so as not to neglect infrequently detected compounds that could contribute significantly to risk if exposure were to occur In this screen, maximum concentrations of infrequently detected compounds (4,4-DDT, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, and PCBs) were compared to risk-based screening values using the approach outlined in Section 2 5 and described in greater detail in Appendix B Complete results of the evaluation are shown in Tables B-7 and B-8 The infrequently detected compounds in surface soils were not present at concentrations greater than the screening values, and therefore, they do not warrant inclusion in the risk assessment Benzo(ghi)perylene and delta-BHC are not included in the risk-based screen because the EPA has not established toxicity factors for these compounds

## 5.6 SUMMARY OF CHEMICALS OF CONCERN IN SURFACE SOIL

Chemicals of concern in surface soils in OU-2 are plutonium-239/249 and americium-241 Chromium, detected in slightly elevated concentrations in two samples near source areas, is retained as a special-case chemical of potential concern for separate evaluation in the risk assessment

**TABLE 5-1**
**ROCKY FLATS PLANT OU-2**
**SUMMARY OF BACKGROUND COMPARISON**
**METALS IN SURFACE SOIL, mg/kg**

| Analyte | DF % (1) | % Data > 95% UTL (1) | ANOVA p (2) | Potential Contaminant? No (3) | Potential Contaminant? Yes (4) | Spatial/Temporal/Other (see text) | OU-2 Contam-inant? |
|---|---|---|---|---|---|---|---|
| Aluminum | 100 | 0 | 0 14* | x | | | No |
| Antimony | 0 | 0 | - | x | | | No |
| Arsenic | 100 | 0 | <0 01* | x | | | No |
| Barium | 100 | 0 | <0 01 * | x | | | No |
| Beryllium | 3 | 0 | 0 05 | x | | | No |
| Cadmium | 13 | 0 | 0 02 | | ? | OU2 Max (2 2 mg/kg) < bknd max (2 5 mg/kg) | No |
| Cesium | 0 | 0 | - | x | | | No |
| Chromium | 100 | 4 8 | 0 05 | x | | | No |
| Cobalt | 100 | 0 | 0 90 | x | | | No |
| Copper | 100 | 0 | 0 06 | x | | | No |
| Lead | 100 | 4 8 | 0 82 | x | | | No |
| Lithium | 100 | 4 8 | <0 01* | x | | | No |
| Manganese | 100 | 0 | 0 14 | x | | | No |
| Mercury | 0 | 0 | - | x | | | No |
| Molybdenum | 3 | 0 | 0 18 | x | | | No |
| Nickel | 100 | 2 4 | 0 73 | x | | | No |
| Selenium | 8 | 2 4 | <0 01 | | ? | OU2 Max (0 9 mg/kg) < bknd max (1 0 mg/kg) | No |
| Silver | 0 | 0 | - | x | | | No |
| Strontium | 100 | 4 8 | 0 92 | x | | | No |
| Thallium | 3 | 0 | <0 01 | | ? | Detected in 1 of 40 samples at 0 5 mg/kg | No |
| Tin | 40 | 2 4 | <0 01 | | ? | 1 result > bknd UTL, at Indiana St. | No |
| Vanadium | 100 | 2 4 | 0 34 | x | | | No |
| Zinc | 100 | 0 | 0 30 | x | | | No |

(1) Detection frequency and UTL comparison from Table A-7
(2) Table A-15 p < 0 05 is considered significant.
(3) <5% data exceeds 95% UTL and p > 0 05
(4) > 5% data exceeds 95% UTL and p < 0 05
? Either > 5% data exceeds 95% UTL or p < 0 05
* Background mean is equal to or exceeds OU2 mean

(4034-263-0049-540)(RTS-1 XLS)(8/23/93 5 20 PM)

**TABLE 5-2**
**ROCKY FLATS PLANT OU-2**
**SUMMARY OF BACKGROUND COMPARISON**
**RADIONUCLIDES IN SURFACE SOIL, pCi/g**

| Analyte | DF % (1) | % Data > 95% UTL (1) | ANOVA p (2) | Potential Contaminant? No (3) | Potential Contaminant? Yes (4) | Spatial/Temporal/Other (see text) | OU-2 Contam-inant? |
|---|---|---|---|---|---|---|---|
| Americium 241 | 100 | 95 | <0 01 | | x | Probable contaminant | Yes |
| Cesium 137 | 96 | 0 | <0 01* | x | | | No |
| Plutonium 239,240 | 100 | 100 | - | | x | Probable contaminant | Yes |
| Radium 226 | 100 | 12 | 0 11 | | ? | 3 results > bknd, max at Indiana St | No |
| Radium 228 | 100 | 0 | 0 66 | x | | | No |
| Strontium 89,90 | 96 | 4 | 0 55 | x | | | No |
| Uranium 233/234 | 100 | 28 | 0 15 | | x | Probable contaminant based on UTL test and spatial anlaysis | Yes |
| Uranium 235 | 100 | 22 | 0 39 | | x | Probable contaminant based on UTL test and spatial anlaysis | Yes |
| Uranium 238 | 100 | 23 | 0 085 | | x | Probable contaminant based on UTL test and spatial anlaysis | Yes |
| Uranium 233,238,239 | 100 | NE | NE | | ? | Probable contaminant based on spatial anlaysis | Yes |

(1) Detection frequency and UTL comparison from Table A-8
(2) Table A-16 p < 0 05 is considered significant
(3) <5% data exceeds 95% UTL and p > 0 05
(4) > 5% data exceeds 95% UTL and p < 0 05
* Background mean exceeds OU2 mean
NE = Not evalauted, no background analyses for this analyte group
Either > 5% data exceeds 95% UTL or p < 0 05
Test not performed because OU-2 data clearly exceed background. See Tables A-8 and A-15

## TABLE 5-3

### ROCKY FLATS PLANT OU-2
### ORGANIC COMPOUNDS DETECTED AT
### 5% OR GREATER FREQUENCY
### SURFACE SOIL

| | Maximum Concentration (mg/kg) | Detection Frequency % |
|---|---|---|
| Benzo(a)anthracene | 0 160 | 17 |
| Benzo(a)pyrene | 0 160 | 17 |
| Benzo(b)fluoranthene | 0 24 | 17 |
| Benzoic Acid | 0 7 | 88 |
| Bis(2-ethylhexyl) phthalate | 0 51 | 21 |
| Chrysene | 0 2 | 23 |
| Fluoranthene | 0 39 | 38 |
| Phenanthrene | 0 23 | 25 |
| Pyrene | 0 35 | 46 |

## TABLE 5-4

### ROCKY FLATS PLANT OU-2
### ORGANIC COMPOUNDS DETECTED AT LESS THAN 5% FREQUENCY
### SURFACE SOIL

| | Maximum Concentration mg/kg | Detection Frequency % |
|---|---|---|
| Benzo(g,h,ı)perylene | 0 061 | 4 |
| Benzo(k)fluoranthene | 0 076 | 4 |
| Dı-n-butyl phthalate | 1 0 | 2 |
| Indeno(1,2,3-cd) perylene | 0 83 | 4 |
| 4,4'-DDT | 0 026 | 2 |
| Aroclor-1254 | 0 97 | 4 |
| Aroclor-1260 | 0 66 | 4 |
| delta-BHC | 0 023 | 2 |

## TABLE 5-5

## ROCKY FLATS OU-2
## CONCENTRATION/TOXICITY SCREEN
## SURFACE SOIL
## RADIONUCLIDES

| Chemical | Maximum Value (pCi/g) | Inhalation Slope Factor | Oral Slope Factor | Risk Factor | Risk Index | Rank | Cumulative Percent |
|---|---|---|---|---|---|---|---|
| plutonium-239/240(1) | 7300 | 3 80E-08 | 2 30E-10 | 2 77E-04 | 9 86E-01 | 1 | 98 6 |
| americium-241(1) | 110 | 3 20E-08 | 2 40E-10 | 3 52E-06 | 1 25E-02 | 2 | 99 8 |
| uranium-233/238/239 (1) | 7 74 | 2 70E-08 | 1 60E-11 | 2 09E-07 | 7 43E-04 | 3 | 99 9 |
| uranium-238 (1) | 7 26 | 2 40E-08 | 1 60E-11 | 1 74E-07 | 6 19E-04 | 4 | 100 0 |
| uranium- 233/234 (1) | 3 58 | 2 70E-08 | 1 60E-11 | 9 67E-08 | 3 43E-04 | 5 | 100 0 |
| uranium-235 (1) | 0 68 | 2 50E-08 | 1 60E-11 | 1 70E-08 | 6 04E-05 | 6 | 100 0 |
| Total Risk Factor | | | | 2 81E-04 | | | |

**Sources**

(1) Heast 1992

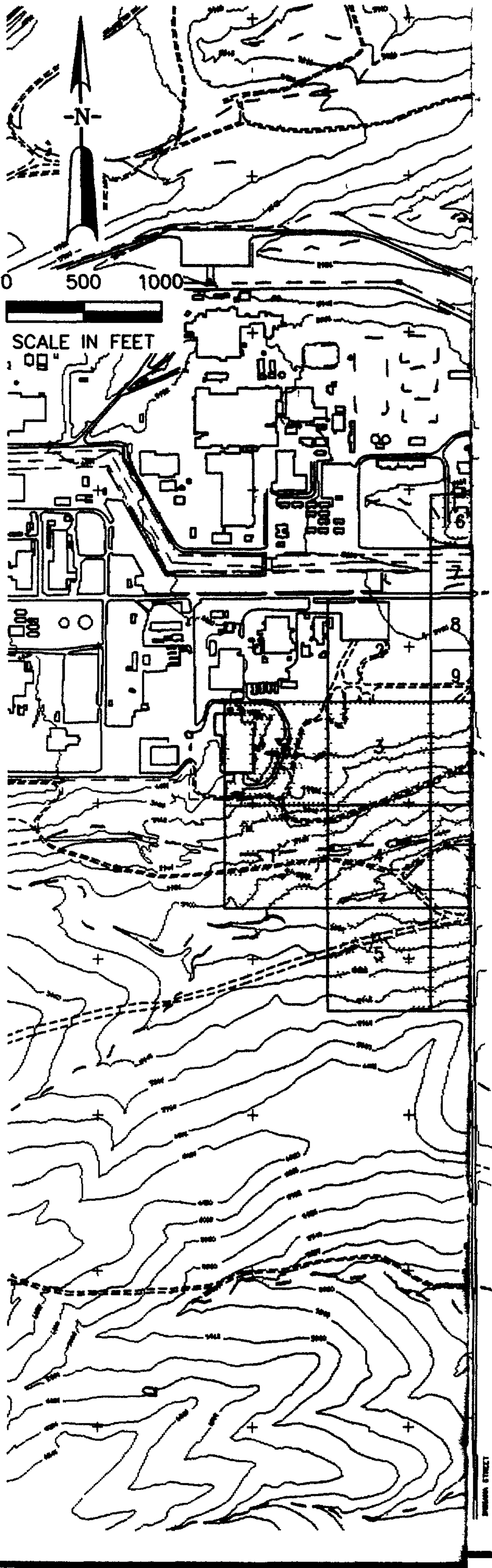
Slope factors are in units of 1/pCi

**TABLE 5-6**
**ROCKY FLATS PLANT OU-2**
**CHEMICALS OF CONCERN**
**SURFACE SOIL**

| |
|---|
| Plutonium-239/240 |
| Americium-241 |

**SPECIAL CASE**
**CHEMICAL OF CONCERN**

| |
|---|
| Chromium |




## EXPLANATION

| | |
|---|---|
| 1 | 10-ACRE SAMPLING PLOT LOCATION |
| 6 | 2 5-ACRE SAMPLING PLOT LOCATION |
| 2 | 10-ACRE PLOT NOT SAMPLED |
| 7 | 2.5-ACRE PLOT NOT SAMPLED |
| SW-50 ● | SURFACE WATER SAMPLING LOCATION |

U S DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO 2
CHEMICALS OF CONCERN
TECHNICAL MEMORANDUM NO 9

1991 RADIONUCLIDE SURFICIAL
SOIL SAMPLING PLOT LOCATIONS

FIGURE 5-1 AUGUST 1993

OU2TM951 1=1000

NOTICE

This document (or documents) is oversized for 16mm microfilming, but is available in its entirety on the 35mm fiche card referenced below:

Document # 000781

Titled: 1993 Surficial Soil Sampling Plot Locations

Fiche location: A-OU02-M1

## 6.0
## REFERENCES


DOE 1993a Technical Memorandum No 5 Exposure Scenarios Human Health Risk Assessment 903 Pad, Mound, and East Trenches Area, Operable Unit No 2 Draft Final Rocky Flats Plant

DOE 1993b Final Technician Memorandum No 8 Revised Phase II RFI/RI Work Plan (Bedrock), 903 Pad Mound, and East Trenches Area, (Operable Unit No 2) Rocky Flats Plant May 1993

EG&G 1992 Final Background Geochemical Characterization Report, Rocky Flats Plant, Golden, Colorado September

EPA 1989 Risk Assessment Guidance for Superfund- Volume I, Human Health Evaluation Manual (Part A) EPA/540/1-89/002 December

EPA 1991 Health Effects Assessment Summary Tables (HEAST) Annual FY-1991 OERR 9200 6-303

EPA 1992a Health Effects Assessment Summary Tables (HEAST) Annual FY-1992 OERR 9200 6-303 March

EPA 1992b EPA Region IV 1991 Toxic Equivalency Factors for Polycyclic Aromatic Hydrocarbons February 1992

EPA 1993 Integrated Risk Information System (IRIS) On-line database

## APPENDIX A
## BACKGROUND COMPARISON
## FOR METALS AND RADIONUCLIDES

Concentrations of metals and radionuclides detected in subsurface soil and groundwater in OU-2 were compared to background concentrations reported in the Final Background Geochemical Characterization Report, Rocky Flats Plant (EG&G September 1992) to help distinguish inorganic compounds that are naturally-occurring within background range from compounds that occur in elevated concentrations due to chemical releases in OU-2 OU-2 surface soil data were compared to background levels determined from data collected in the Rock Creek area in 1991 and 1993 The procedures applied in the background comparison are shown in the flow chart in Figure A-1 Each step is briefly described below

Step 1 - Categorize OU-2 Samples and Background Data

Background data and OU-2 samples were classified by lithologic unit (for groundwater) and by surface vs subsurface soil Data from OU-2 subsurface soil samples collected above water table were used to compare to background to avoid the potential for cross-contamination from groundwater

Step 2 - Comparison to Background Tolerance Limits

Analytical results for each detected inorganic analyte were compared to the 95% upper tolerance limit (UTL) of the background results If 5% or more of the data exceeded the UTL, the compound was retained for further evaluation If less than 5% of the data exceeded the UTL, the compound was considered to be within background range, although further analysis by ANOVA may be performed Tolerance limits define a range that contains at least P% of a population with a probability (p) (level of confidence) A probability is associated with the tolerance limits since they are estimated from the data set and, therefore, have some level of uncertainty associated with them For the tolerance limit to be useful in decision making, both "p" and "P" are chosen to be large, in this case p=0 95 and P=95% A one-sided tolerance limit is appropriate for analytes for which an increase over background may be indicative of potential contamination If less than 5% of the non-background results for a given analyte exceeded the upper 95% tolerance limit (UTL) of the background results, then the non-background and background populations were considered to be similar Consequently, these analytes can be deleted from the list of potential contaminants based on background comparison If 5% or more of the non-background results exceed the background UTL, Step 3 is performed The comparison to UTL was performed using one-half the detection limit as the concentration in samples in which the compound was reported as non-detect

Step 3 - Percentage of Non-Detections

If there are more than 50% non-detections in the grouped background and non-background observations, the Wilcoxon Rank Sum test or the Kruskal-Wallis test is an appropriate analysis The Kruskal-Wallis test is an extension of the Wilcoxon Rank Sum test to more than one population

Step 4 - Wilcoxon Sum Rank Test

The Wilcoxon Rank Sum test or the Kruskal-Wallis test may be used if there are more than 50% non-detections in the grouped background and non-background data In the background comparison performed for this technical memorandum, data were evaluated using either the nonparametric ANOVA (Kruskal-Wallis) or the parametric ANOVA (Steps 5 through 8) ANOVA requires at least three observations from the non-background area

Step 5 - Distribution of Data

Were the data normally distributed? In using ANOVA it is necessary to identify sample distributions (Step 5) and equality of variances (Step 6) to determine whether non-parametric (Step 7) or parametric (Step 8) ANOVA methods should be used Non-detections were included using a value equal to one-half of the detection limit

Normality of the data was evaluated by examining the results of the Shapiro-Wilks test or the Lilliefors variation on the Kolmogov-Smirnoff test If the data were normally distributed, Step 6 was performed next If the data were not normally distributed, it was determined if the degree of non-normality was sufficient to invalidate the parametric ANOVA test If the data transformations could not achieve normality, then non-parametric statistical methods (Step 7) were used for evaluating the data Variance is a measure of dispersion of a set of observations around the mean of a random variable If the variances of the background and non-background populations are equal, and the data are normally distributed (Step 5), then parametric one-way ANOVA tests are used

Step 6 - Equality of Variance

Are the variances of the background and the non-background data equal? (This step only applies to normally distributed data )

Step 7 - Non-parametric Test

If data are not normally distributed or the variances are not equal, the Kruskal-Wallis non-parametric ANOVA is used The non-parametric ANOVA evaluates differences in the mean rankings of the data (rather than the raw data or transformations of the raw data)

Step 8 - Parametric Test

If both the background and non-background data are normally distributed and the variances are equal, then a parametric ANOVA test is used

The tables on the following pages present the results of the background comparisons for metals and radionuclides in groundwater, subsurface soil, and surface soil Explanatory notes precede the tables

| | | |
|---|---|---|
| Table A-1 | 95% UTL Comparison | Dissolved Metals in Groundwater |
| Table A-2 | 95% UTL Comparison | Total Metals in Groundwater (No 1 Sandstone only) |
| Table A-3 | 95% UTL Comparison | Total Radionuclides in Groundwater (No 1 Sandstone) |
| Table A-4 | 95% UTL Comparison | Dissolved Radionuclides in Groundwater (UHSU) |
| Table A-5 | 95% UTL Comparison | Metals in Subsurface Soil |
| Table A-6 | 95% UTL Comparison | Radionuclides in Subsurface Soil |
| Table A-7 | 95% UTL Comparison | Metals in Surface Soil |
| Table A-8 | 95% UTL Comparison | Radionuclides in Surface Soil |
| Table A-9 | ANOVA Comparison | Total Metals in Groundwater (No 1 Sandstone) |
| Table A-10 | ANOVA Comparison | Dissolved Metals in Groundwater (UHSU) |
| Table A-11 | ANOVA Comparison | Total Radionuclides in Groundwater (No 1 Sandstone) |
| Table A-12 | Background Comparison | Dissolved Radionuclides in Groundwater |
| Table A-13 | Background Comparison | Metals in Subsurface Soil |
| Table A-14 | Background Comparison | Radionuclides in Subsurface Soil |
| Table A-15 | Background Comparison | Metals in Surface Soil |
| Table A-16 | Background Comparison | Radionuclides in Surface Soil |

## EXPLANATORY NOTES
## 95% UTL COMPARISON AND ANOVA TABLES
## ROCKY FLATS OU-2

<u>Groundwater</u> Background comparisons for metals and radionuclides in groundwater were done two ways (1) No 1 Sandstone separately and (2) an aggregate of the No 1 Sandstone, Rocky Flats alluvium, colluvium, and valley fill alluvium (Upper Hydrostratigraphic Unit or UHSU) The No 1 Sandstone is the only lithologic unit that might possibly support a water supply well Yields in other units are seasonal and so low that supply of water would be depleted within days under a typical domestic pumping scenario Therefore, the No 1 Sandstone is the appropriate lithologic unit to evaluate in selecting chemicals of concern for a hypothetical on-site residential groundwater exposure scenario (Total metals and radionuclides were included in this scenario ) Combined data from UHSU were used to identify metals and radionuclides for further consideration in selecting chemicals of concern for fate and transport modeling (Dissolved metals and radionuclides were included in this scenario )

<u>Subsurface Soil</u> OU-2 subsurface soil data used in the background comparison were from borehole samples collected above the water table Soil samples collected below water table were not included in the comparison because of the potential for cross-contamination from groundwater In this way, data from subsurface soil samples are independent of groundwater contaminants

<u>Surface Soil</u> OU-2 surface soil data used in the comparison to background included all data submitted to Woodward-Clyde by June 6, 1993

<u>Comparison to Background UTLs</u> OU-2 data were compared to the 95% UTL of the background data If no more than 5 percent of OU-2 results for a given analyte exceeded the 95th percent UTL of the background data, the analyte can be considered to be within background range Additional evaluation by ANOVA may be performed

<u>ANOVA Comparison Tables "Consider Further".</u> The last column of each ANOVA Comparison Table contains a yes (Y) or no (N) to indicate whether the metal or radionuclide will be considered further in selection of contaminants of concern A "yes" means that the metal or radionuclide appeared to exceed background levels based on the ANOVA analysis (or that there were no site-specific background data available for comparison) OU-2 data were also evaluated by comparing to the 95% UTL of the background data (see above) Final selection

of chemicals of concern was made following further evaluation of the data (e g , frequency of detection, concentration/toxicity screens, and spatial distribution)

<u>Use of Non-detect Values in Calculations</u> For metals, the UTL and ANOVA tests were performed using one-half the detection limit as the concentration in samples in which the analyte was not detected For radionuclides, zero values and negative results were not included in the calculation

# TABLE A-1
# ROCKY FLATS PLANT OU-2
# 95% UTL COMPARISON
# TOTAL METALS IN GROUNDWATER, µg/L
# NO. 1 SANDSTONE

| | OU-2 Detected | | | Bknd | Background | % of OU-2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF % | Max | 95% UTL(1) | > 95% UTL (2) |
| Aluminum | 870 | 128,000 | 100 | 7,000 | 6,262 | 82 |
| Antimony | 10 | 297 | 20 | 1,610 | 933 | 0 |
| Arsenic | 1 | 11 | 77 | 7 | 7 | 6 |
| Barium | 99 | 3,090 | 100 | 1,810 | 1,050 | 12 |
| Beryllium | 1 | 19 | 63 | 160 | 89 | 0 |
| Cadmium | 1 | 11 | 36 | 1,720 | 951 | 0 |
| Cesium | 30 | 80 | 9 | 500 | 800 | 0 |
| Chromium | 4 | 209 | 75 | 1,590 | 881 | 0 |
| Cobalt | 3 | 99 | 68 | 1,620 | 905 | 0 |
| Copper | 4 | 206 | 83 | 1,750 | 972 | 0 |
| Cyanide | 1 | 27 | 44 | 8 | 6 | 16 |
| Lead | 1 | 171 | 99 | 15 | 10 | 65 |
| Lithium | 4 | 84 | 93 | 100 | 89 | 0 |
| Manganese | 9 | 4,920 | 100 | 710 | 438 | 40 |
| Mercury | 0 3 | 0 8 | 15 | 0 1 | 0 2 | 15 |
| Molybdenum | 3 | 26 | 49 | 1,600 | 915 | 0 |
| Nickel | 4 | 188 | 85 | 1,660 | 925 | 0 |
| Selenium | 1 | 6 | 50 | 80 | 49 | 0 |
| Silver | 2 | 4 | 13 | 300 | 163 | 0 |
| Strontium | 262 | 1,370 | 99 | 1,110 | 921 | 6 |
| Thallium | 1 | 3 | 15 | 2 | 8 | 0 |
| Tin | 14 | 87 | 21 | 100 | 168 | 0 |
| Vanadium | 7 | 345 | 100 | 1,670 | 929 | 0 |
| Zinc | 14 | 839 | 98 | 1,800 | 1,023 | 0 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G, 1992

(2) UTL comparison is performed using one-half the detection limit for results reported as non-detect Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data (i e , one-half the reporting limits for non-detects) exceeds the 95% UTL of background

DF = Detection frequency

ND = Not detected

**TABLE A-2**
**ROCKY FLATS PLANT OU-2**
**95% UTL COMPARISON**
**TOTAL RADIONUCLIDES IN GROUNDWATER, pCi/L**
**NO 1 SANDSTONE**

| | OU-2 Detected | | | Bknd | Bknd 95% | % of OU-2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF | Max | UTL (1) | >95% UTL |
| Americium-241 | 0 001 | 1 09 | 86/93 | 0 08 | 0 044 | 12 |
| Cesium-137 | 0 04 | 1 66 | 49/49 | 0 89 | 0 83 | 14 |
| Plutonium-239/240 | 0 0005 | 5 02 | 100/102 | 0 009 | 0 007 | 64 |
| Strontium-89/90(2) | 0 39 | 0 39 | 1/4 | 0 17 | 0 44 | 0 |
| Tritium | ND | - | 0/12 | 1350 | 2786 | 0 |
| Uranium-233/234 | 3 7 | 8 2 | 4/4 | 17 5 | 24 | 0 |
| Uranium-235 | 0 06 | 0 28 | 4/4 | 0 75 | 1 05 | 0 |
| Uranium-238 | 2 | 6 4 | 4/4 | 10 6 | 2 5 | 0 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992
(2) Only 3 background data points and 4 OU-2 data points (3 of the 4 are ND)

DF = Detection frequency (no detects/no samples)
ND = not detected
- No data

TABLE A-3
ROCKY FLATS PLANT OU-2
95% UTL COMPARISON
DISSOLVED METALS IN GROUNDWATER, µg/L
USHU

| | OU-2 Detected | | | Bknd | Background | % of OU-2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF % | Max | 95% UTL(1) | >95% UTL (2) |
| Aluminum | 20 | 367 | 74 | 8610 | 1318 | 0 |
| Antimony | 8 | 88 | 17 | 60 | 46 | 9 |
| Arsenic | 1 | 8 | 11 | 15 | 7 | 1 |
| Barium | 23 | 675 | 100 | 203 | 169 | 40 |
| Beryllium | 1 | 3 | 4 | 5 | 3 | 0 |
| Cadmium | 1 | 98 | 11 | 9 | 5 | 2 |
| Cesium | 30 | 120 | 20 | 2500 | 1177 | 0 |
| Chromium | 3 | 23 | 24 | 23 | 14 | 6 |
| Cobalt | 3 | 13 | 6 | 50 | 28 | 0 |
| Copper | 1 | 19 | 25 | 25 | 17 | 2 |
| Lead | 1 | 10 | 6 | 64 | 13 | 0 |
| Lithium | 2 | 127 | 79 | 281 | 149 | 0 |
| Manganese | 1 | 3940 | 73 | 934 | 216 | 23 |
| Mercury | 0 21 | 0 32 | 3 | 1 2 | 0 38 | 0 |
| Molybdenum | 2 | 67 | 45 | 114 | 61 | 1 |
| Nickel | 2 | 1210 | 31 | 40 | 25 | 6 |
| Selenium | 1 | 168 | 36 | 607 | 290 | 0 |
| Silver | 2 | 25 | 9 | 13600 | 2133 | 0 |
| Strontium | 240 | 3040 | 99 | 8730 | 2148 | 2 |
| Thallium | 1 | 2 | 6 | 328 | 4 | 0 |
| Tin | 12 | 89 | 10 | 8830 | 1367 | 0 |
| Vanadium | 3 | 12 | 69 | 57 | 28 | 0 |
| Zinc | 1 | 759 | 67 | 137 | 51 | 3 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992

(2) UTL comparison is performed using one-half the detection limit for results reported as non-detect Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data (i e , one-half the reporting limits for non-detects) exceeds the 95% UTL of background

*DF = Detection frequency*

**TABLE A-4**
**ROCKY FLATS PLANT OU-2**
**95% UTL COMPARISON**
**DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L**
**UHSU**

| | OU-2 Detected | | | Bknd | Bknd 95% | % OU2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF | Max | UTL (1) | > 95% UTL |
| Americium-241 | 0 001 | 21 3 | 10/10 | 0 28 | 0 10 | 30 |
| Cesium-137 | 0 25 | 0 53 | 2/11 | -- | NE | * |
| Plutonium-239/240 | 0 0003 | 0 81 | 10/10 | 0 11(2) | NE | * |
| Radium-226 | 0 12 | 2 8 | 52/53 | 3 0 | 1 84 | 2 |
| Strontium-89/90 | 0 009 | 2 1 | 165/184 | 1 5 | 0 82 | 7 |
| Tritium | 0 96 | 1753 | 181/181 | 561 | 334 | 8 |
| Uranium-233/234 | 0 18 | 42 62 | 230/230 | 199 5 | 53 | 0 |
| Uranium-235 | 0 02 | 1 5 | 179/197 | 4 8 | 1 7 | 0 |
| Uranium-238 | 0 17 | 76 | 224/224 | 135 6 | 37 | 1 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992
(2) One data point

DF = Detection frequency (no detects/no samples)
NE = not evaluated   Data insufficient to calculate 95% UTL
* Comparison cannot be made

**TABLE A-5**
**ROCKY FLATS PLANT OU-2**
**95% UTL COMPARISON**
**METALS IN SUBSURFACE SOIL, mg/kg**

| | OU-2 Detected | | | Bknd | Background | % of OU-2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF % | Max | 95% UTL(1) | > 95% UTL (2) |
| Aluminum | 1,190 | 27,900 | 100 | 102,000 | 31,979 | 0 |
| Antimony | 4 | 24 | 4 | 16 | 12 | 5 |
| Arsenic | 1 | 37 | 94 | 42 | 12 | 11 |
| Barium | 10 | 589 | 83 | 777 | 270 | 2 |
| Beryllium | 0 3 | 23 | 47 | 24 | 13 | 0 4 |
| Cadmium | 1 | 10 | 45 | 2 | 1 | 36 |
| Cesium | 1 | 5 | 91 | 274 | 208 | 7 |
| Chromium | 2 | 127 | 98 | 176 | 61 | 1 |
| Cobalt | 1 | 78 | 55 | 30 | 15 | 2 |
| Copper | 3 | 132 | 84 | 123 | 35 | 1 |
| Lead | 1 | 86 | 99 | 40 | 27 | 1 |
| Lithium | 1 | 25 | 91 | 83 | 24 | 1 |
| Manganese | 4 | 1,610 | 100 | 3,330 | 822 | 1 |
| Mercury | 0 06 | 114 | 20 | 6 | 1 | 1 |
| Molybdenum | 1 | 19 | 33 | 68 | 31 | 7 |
| Nickel | 4 | 63 | 79 | 193 | 57 | 0 4 |
| Selenium | 0 4 | 2 | 7 | 14 | 4 5 | 0 |
| Silver | 1 | 96 | 13 | 41 | 22 5 | 1 |
| Strontium | 4 | 246 | 82 | 242 | 127 | 5 |
| Thallium | 0 2 | 1 | 12 | 10 | 3 | 0 |
| Tin | 22 | 53 | 24 | 441 | 268 | 0 |
| Vanadium | 4 | 53 | 97 | 283 | 80 | 0 |
| Zinc | 4 | 437 | 98 | 486 | 131 | 2 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992
(2) UTL Comparison is performed using one-half the detection limit for results reported as non-detect Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data (i e , one-half the reporting limits for non-detects) exceeds the 95% UTL of background

DF = Detection frequency

**TABLE A-6**
**ROCKY FLATS PLANT OU-2**
**95% UTL COMPARISON**
**RADIONUCLIDES IN SUBSURFACE SOIL, pCi/g**

| Analyte | OU-2 Detected Min | OU-2 Detected Max | OU-2 Detected DF % | Bknd Max | Bknd 95% UTL (1) | % of OU-2 data >95% UTL |
|---|---|---|---|---|---|---|
| Americium-241 | 0 0009 | 7 2 | 83 | 0 01 | 0 01 | 77 |
| Cesium-137 | 0 005 | 2 4 | 66 | 0 2 | 0 3 | 33 |
| Plutonium-239/240 | 0 006 | 68 | 78 | 0 03 | 0 02 | 54 |
| Radium-226 | 0 32 | 1 9 | 90 | 1 3 | 1 3 | 3 |
| Radium-228 | 0 52 | 2 6 | 100 | 2 2 | 2 0 | 9 |
| Strontium-89/90 | 0 002 | 0 8 | 73 | 1 2 | 0 9 | 0 |
| Strontium-90 | 0 01 | 0 9 | 100 | - | - | (2) |
| Tritium (pCi/L) | 9 63 | 1500 | 74 | 440 | 366 | 7 |
| Uranium-233/234 | 0 04 | 192 | 100 | 8 9 | 2 5 | 1 |
| Uranium-235 | 0 | 11 5 | 88 | 0 3 | 0 2 | 1 7 |
| Uranium-238 | 0 09 | 113 | 100 | 3 2 | 1 5 | 2 6 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G, 1992
(2) None of the Strontium-90 data points exceeds the 95% UTL concentration for Strontium-89/90

DF = Detection frequency
NE = not evaluated Data insufficient to calculate 95% UTL
\- No data

**TABLE A-7**
**ROCKY FLATS PLANT OU-2**
**95% UTL COMPARISON**
**METALS IN SURFACE SOIL, mg/kg**

| | OU-2 Detected | | | Bknd | Bknd 95% | % of OU-2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF% | Max | UTL (1) | >95% UTL(2) |
| Aluminum | 6,170 | 17,900 | 100 | 21,800 | 22,514 | 0 |
| Antimony | ND | ND | 0 | 25 | 16 16 | 0 |
| Arsenic | 1 5 | 6 1 | 100 | 8 7 | 10 13 | 0 |
| Barium | 71 7 | 190 | 100 | 470 | 405 96 | 0 |
| Beryllium | * | 1 3 | 3 | 2 5 | 3 56 | 0 |
| Cadmium | 1 3 | 2 2 | 13 | 2 5 | 3 44 | 0 |
| Cesium | ND | ND | 0 | 250 | 198 92 | 0 |
| Chromium | 8 5 | 29 5 | 100 | 22 | 23 46 | 4 8 |
| Cobalt | 4 3 | 9 6 | 100 | 24 | 17 10 | 0 |
| Copper | 5 | 16 4 | 100 | 24 | 24 18 | 0 |
| Lead | 14 7 | 63 4 | 100 | 51 | 53 53 | 4 8 |
| Lithium | 4 5 | 22 9 | 100 | 18 | 18 | 4 8 |
| Manganese | 192 | 1,110 | 100 | 2,220 | 1,327 28 | 0 |
| Mercury | ND | ND | 0 | 0 1 | 0 17 | 0 |
| Molybdenum | * | 5 3 | 3 | 20 | 27 76 | 0 |
| Nickel | 6 1 | 21 6 | 100 | 19 | 21 04 | 2 4 |
| Selenium | 0 47 | 0 9 | 8 | 1 | 0 8 | 2 4 |
| Silver | ND | ND | 0 | 5 | 3 33 | 0 |
| Strontium | 15 | 100 | 100 | 109 | 81 55 | 4 8 |
| Thallium | * | 0 5 | 3 | 1 | 1 14 | 0 |
| Tin | 24 | 93 3 | 40 | 50 | 56 74 | 2 4 |
| Vanadium | 17 5 | 51 1 | 100 | 47 | 50 63 | 2 4 |
| Zinc | 33 8 | 89 3 | 100 | 94 | 92 78 | 0 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant EG&G, 1992

(2) UTL comparison is performed using one-half the detection limit for results reported as non-detect Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even though the UTL comparison shows that a certain percentage of OU-2 data (i e , one-half the reporting limits for non-detects) exceeds the 95% UTL of background

DF = Detection frequency
ND = Not detected
* Only detected in 1 of 40 samples Result is shown as maximum

# TABLE A-8
# ROCKY FLATS PLANT OU-2
# 95% UTL COMPARISON
# RADIONUCLIDES IN SURFACE SOIL, pCi/g

| Analyte | OU-2 Detected | | | Bknd | Bknd 95% | % of OU-2 data |
|---|---|---|---|---|---|---|
| | Min | Max | DF% | Max | UTL (1) | >95% UTL |
| Americium-241 | 0.01 | 110 | 100 | 0.04 | 0.042 | 95 |
| Cesium-137 | 0.16 | 1.8 | 96 | 2.5 | 2.62 | 0 |
| Plutonium-239/240 | 0.3 | 7,300 | 100 | 0.1 | 0.10 | 100 |
| Radium-226 | 0.6 | 11.8 | 100 | 1.1 | 1.28 | 12 |
| Radium-228 | 1.3 | 3.5 | 100 | 2.9 | 3.57 | 0 |
| Strontium-89/90 | 0.2 | 3.5 | 96 | 1.0 | 1.46 | 4 |
| Uranium-233/234 | 0.8 | 3.6 | 100 | 1.47 | 1.50 | 28 |
| Uranium 235 | 0.01 | 0.68 | 100 | 0.15 | 0.09 | 22 |
| Uranium 238 | 0.89 | 7.3 | 100 | 1.52 | 1.62 | 23 |
| Uranium 233/238/239 | 1.09 | 7.7 | 100 | NE | NE | * |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G, 1992

DF = Detection frequency
NE = Not evaluated. No background analysis for this analyte group
* Comparison cannot be made

# TABLE A-9
# ROCKY FLATS PLANT OU-2
# ANOVA COMPARISON
# TOTAL METALS IN GROUNDWATER, µg/L
# NO. 1 SANDSTONE

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test[1] | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean[2] | Consider Further? |
| Aluminum | 1,383 | 2,108 | 18,702 | 26,247 | No | Kruskal | 41.52 | <0.01 | Y | N | Y |
| Antimony | 170 | 354 | 47 | 160 | No | Kruskal | 0.23 | 0.63 | N | Y | N |
| Arsenic | 5 | 0.8 | 4 | 2 | No | Kruskal | 5.63 | 0.02 | Y | Y | N |
| Barium | 181 | 376 | 434 | 510 | No | Kruskal | 38.68 | <0.01 | Y | N | Y |
| Beryllium | 10 | 34 | 4 | 16 | No | Kruskal | 4.48 | <0.03 | Y | Y | N |
| Cadmium | 84 | 375 | 20 | 174 | No | Kruskal | 0.02 | 0.89 | N | Y | N |
| Cesium | 439 | 157 | 416 | 152 | No | Kruskal | 1.55 | 0.21 | N | Y | N |
| Chromium | 82 | 345 | 41 | 159 | No | Kruskal | 10.73 | <0.01 | Y | Y | N |
| Cobalt | 98 | 349 | 36 | 159 | No | Kruskal | 6.20 | 0.01 | Y | Y | N |
| Copper | 96 | 379 | 45 | 175 | No | Kruskal | 1.15 | 0.28 | N | Y | N |
| Cyanide | 5 | 0.6 | 5 | 3 | No | Kruskal | 0.02 | 0.88 | N | Y | N |
| Lead | 3 | 3 | 21 | 30 | No | Kruskal | 34.19 | <0.01 | Y | N | Y |
| Lithium | 33 | 25 | 25 | 21 | Yes | ANOVA | 4.28 | 0.04 | Y | Y | N |
| Manganese | 75 | 157 | 528 | 832 | No | Kruskal | 33.71 | <0.01 | Y | N | Y |
| Mercury | ND | - | 0.16 | 0.11 | No | Kruskal | 1.08 | 0.30 | N | N | N |
| Molybdenum | 127 | 341 | 58 | 161 | No | Kruskal | 1.53 | 0.22 | N | Y | N |
| Nickel | 98 | 358 | 46 | 165 | No | Kruskal | 0.13 | 0.72 | N | Y | N |
| Selenium | 8 | 18 | 3 | 8 | No | Kruskal | 4.98 | 0.03 | Y | Y | N |

## TABLE A-9
## (Concluded)

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test[1] | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean[2] | Consider Further? |
| Silver | 19 | 64 | 8 | 31 | No | Kruskal | 8 73 | <0 01 | Y | Y | N |
| Strontium | 361 | 242 | 503 | 223 | Yes | ANOVA | 24 90 | <0 01 | Y | N | Y |
| Thallium | 4 | 2 | 4 | 2 | No | Kruskal | 0 34 | 0 56 | N | Y | N |
| Tin | 82 | 35 | 75 | 37 | No | Kruskal | 1 18 | 0 28 | N | Y | N |
| Vanadium | 93 | 362 | 66 | 174 | No | Kruskal | 17 03 | <0 01 | Y | Y | N |
| Zinc | 127 | 387 | 133 | 219 | No | Kruskal | 14 13 | <0 01 | Y | N | Y |

[1] ANOVA comparison is used on normally distributed data The Kruskal analysis is used on non-normally distributed data
[2] If the background mean is higher than OU-2 mean, a statistically significant difference (P<0 05) is not applicable
ND - Not Detected
- No data

## TABLE A-10
## ROCKY FLATS PLANT OU-2
## ANOVA COMPARISON
## TOTAL RADIONUCLIDES IN GROUNDWATER, pCi/L
## NO. 1 SANDSTONE

| Analyte | Background Mean | Background SD | OU-2 Data Mean | OU-2 Data SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean(1) | Consider Further? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Americium 241 | 0 01 | 0 02 | 0 04 | 0 14 | No | Kruskal | 5 06 | 0 02 | Y | N | Y |
| Cesium 137 | 0.29 | 0.230 | 0 46 | 0.38 | Yes | ANOVA | 3.54 | 0 06 | N | N | N |
| Radium 226 | 0.51 | 0.39 | (2) | - | No | Kruskal | 2 00 | 0 16 | N | - | N |
| Plutonium 239, 240 | 0 003 | 0 002 | 0 13 | 0.58 | No | Kruskal | 30.89 | <0 01 | Y | N | Y |
| Strontium 89,90 | 0 11 | 0 05 | 0 16 | 0 16 | No | Kruskal | 0 03 | 0 86 | N | N | N |
| Uranium 233, 234 | 6 | 6 | 5 | 2 | Yes | ANOVA | 0 64 | 0.80 | N | Y | N |
| Uranium 235 | 0.28 | 0 26 | 0 16 | 0 12 | Yes | ANOVA | 0 71 | 0 42 | N | Y | N |
| Uranium 238 | 4 | 5 | 3 | 2 | Yes | ANOVA | 0 02 | 0 91 | N | Y | N |

(1) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0 05) is not applicable
(2) One data point
\- No data

**TABLE A-11**
**ROCKY FLATS PLANT OU-2**
**ANOVA COMPARISON**
**DISSOLVED METALS IN GROUNDWATER, μg/L**
**UHSU**

| Analyte | Background Mean | Background SD | OU-2 Data Mean | OU-2 Data SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | BKG Mean ≥OU2 Mean[1] | Consider Further? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 106 | 630 | 56 | 42 | No | Kruskal | 0 30 | 0 58 | N | Y | N |
| Antimony | 22 | 11 | 26 | 11 | No | Kruskal | 6 69 | <0 01 | Y | N | Y |
| Arsenic | 4 | 2 | 4 | 2 | No | Kruskal | 0 81 | 0 37 | N | Y | N |
| Barium | 84 | 34 | 161 | 75 | No | Kruskal | 159 0 | <0 01 | Y | N | Y |
| Beryllium | 2 | 1 | 2 | 1 | No | Kruskal | 0 30 | 0 59 | N | Y | N |
| Cadmium | 2 | 1 | 3 | 7 | No | Kruskal | 0 59 | 0 44 | N | N | N |
| Cesium | 417 | 221 | 349 | 179 | No | Kruskal | 3 87 | <0 01 | Y | Y | N |
| Chromium | 6 | 3 | 5 | 4 | No | Kruskal | 9 71 | <0 01 | Y | Y | N |
| Cobalt | 19 | 10 | 19 | 10 | No | Kruskal | 0 03 | 0 86 | N | Y | N |
| Copper | 10 | 4 | 8 | 5 | No | Kruskal | 6 52 | 0 01 | Y | Y | N |
| Lead | 3 | 6 | 1 | 1 | No | Kruskal | 29 96 | <0 01 | Y | Y | N |
| Lithium | 41 | 55 | 16 | 23 | No | Kruskal | 36 22 | <0 01 | Y | Y | N |
| Manganese | 34 | 96 | 216 | 536 | No | Kruskal | 28 66 | <0 01 | Y | N | Y |
| Mercury | 0 10 | 0 11 | 0 09 | 0 04 | No | Kruskal | 2 23 | 0 14 | N | Y | N |
| Molybdenum | 48 | 45 | 42 | 45 | No | Kruskal | 1 26 | 0 26 | N | Y | N |
| Nickel | 14 | 8 | 31 | 107 | No | Kruskal | 1 95 | 0 16 | N | N | N |
| Selenium | 12 | 55 | 5 | 20 | No | Kruskal | 13 74 | <0 01 | Y | Y | N |
| Silver | 89 | 1068 | 4 | 2 | No | Kruskal | 20 33 | <0 01 | Y | Y | N |

## TABLE A-11
## (Concluded)

| Analyte | Background Mean | Background SD | OU-2 Data Mean | OU-2 Data SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | BKG Mean ≥OU2 Mean[1] | Consider Further? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Strontium | 436 | 891 | 566 | 409 | No | Kruskal | 73 5 | <0 01 | Y | N | Y |
| Thallium | 5 | 13 | 4 | 2 | No | Kruskal | 0 05 | 0 83 | N | Y | N |
| Tin | 106 | 671 | 75 | 40 | No | Kruskal | 15 18 | <0 01 | Y | Y | N |
| Vanadium | 13 | 11 | 8 | 7 | No | Kruskal | 9 69 | <0 01 | Y | Y | N |
| Zinc | 14 | 19 | 16 | 58 | No | Kruskal | 7 74 | <0 01 | Y | N | Y |

[1] If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0 05) is not applicable

**TABLE A-12**
**ROCKY FLATS PLANT OU-2**
**ANOVA COMPARISON**
**DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L**
**UHSU**

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | BKG Mean >OU2 Mean (1) | Consider Further? |
| Americium 241 | 0 02 | 0 01 | 2 | 7 | No | Kruskal | 0 11 | 0 74 | N | N | N |
| Cesium 137 | – | – | 0 22 | 0 11 | No | Kruskal | – | – | – | – | Y |
| Plutonium 239, 240 | (2) | (2) | 0 11 | 0 25 | No | Kruskal | (2) | (2) | (2) | Y | Y |
| Radium 226 | 0 4 | 0 62 | 0 57 | 0 39 | No | Kruskal | 15 52 | <0 01 | Y | N | Y |
| Strontium 89,90 | 0 36 | 0 24 | 0 4 | 0 33 | No | Kruskal | 0 01 | 0 99 | N | N | N |
| Tritium | 139 | 102 | 175 | 171 | No | Kruskal | 3 59 | 0 06 | N | N | N |
| Uranium 233, 234 | 6 | 24 | 5 | 5 | No | Kruskal | 47 95 | <0 01 | Y | Y | N |
| Uranium 235 | 0 28 | 0 74 | 0 17 | 0 20 | No | Kruskal | 3 74 | 0 053 | N | Y | N |
| Uranium 238 | 4 | 16 7 | 4 | 7 | No | Kruskal | 50 56 | <0 01 | N | Y | N |

(1) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0 05) is not applicable
(2) One background data point ANOVA not performed
– No data

# TABLE A-13
# ROCKY FLATS PLANT OU-2
# ANOVA COMPARISON
# METALS IN SUBSURFACE SOIL, mg/kg
# VADOSE ZONE

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test | Result (Chi Square) | P = | Significantly Different? | Bknd Mean = > OU2 Mean(1) | Consider Further? |
| Aluminum | 11 567 | 10 637 | 10,471 | 4 663 | No | Kruskal | 0 23 | 0 63 | N | Y | N |
| Antimony | 6 | 3 | 8 | 10 | No | Kruskal | 0 63 | 0 43 | N | N | N |
| Arsenic | 4 | 4 | 6 | 5 | No | Kruskal | 35 77 | <0 01 | Y | N | Y |
| Barium | 95 | 91 | 76 | 65 | No | Kruskal | 7 97 | <0 01 | Y | Y | N |
| Beryllium | 4 | 4 | 0 73 | 1 | No | Kruskal | 212 45 | <0 01 | Y | Y | N |
| Cadmium | 0 7 | 0 4 | 1 | 1 | No | Kruskal | 7 79 | <0 01 | Y | N | Y |
| Cesium | 115 | 49 | 38 | 127 | No | Kruskal | 139 77 | <0 01 | Y | Y | N |
| Chromium | 17 | 23 | 13 | 11 | No | Kruskal | 9 65 | <0 01 | Y | Y | N |
| Cobalt | 7 | 4 | 6 | 5 | No | Kruskal | 13 55 | <0 01 | Y | Y | N |
| Copper | 13 | 12 | 10 | 10 | No | Kruskal | 13 21 | <0 01 | Y | Y | N |
| Lead | 12 | 8 | 8 | 8 | No | Kruskal | 29 67 | <0 01 | Y | Y | N |
| Lithium | 9 | 8 | 9 | 4 | No | Kruskal | 0 01 | 0 91 | N | Y | N |
| Manganese | 206 | 321 | 187 | 175 | No | Kruskal | 0 01 | 0 91 | N | Y | N |
| Mercury | 0 26 | 0 58 | 0 51 | 7 | No | Kruskal | 109 51 | <0 01 | Y | N | Y |
| Molybdenum | 14 | 9 | 16 | 13 | No | Kruskal | 0 10 | 0 75 | N | N | N |
| Nickel | 20 | 20 | 12 | 7 | No | Kruskal | 26 62 | <0 01 | Y | Y | N |
| Selenium | 1 | 2 | 0 5 | 0 11 | No | Kruskal | 110 22 | <0 01 | Y | Y | N |
| Silver | 5 | 9 | 2 | 7 | No | Kruskal | 100 70 | <0 01 | Y | Y | N |
| Strontium | 48 | 41 | 40 | 40 | No | Kruskal | 10 67 | <0 01 | Y | Y | N |
| Thallium | 0 82 | 1 1 | 1 | 0 24 | No | Kruskal | 9 59 | <0 01 | Y | N | Y |
| Tin | 65 | 106 | 31 | 24 | No | Kruskal | 1 01 | 0 31 | N | Y | N |
| Vanadium | 29 | 27 | 24 | 10 | No | Kruskal | 4 82 | 0 03 | Y | Y | N |
| Zinc | 40 | 48 | 30 | 33 | No | Kruskal | 11 28 | <0 01 | Y | Y | N |

(1) If the background mean is equal to or higher than OU 2 data mean, a statistically significant difference (P<0 05) is not applicable

**TABLE A-14**
**ROCKY FLATS PLANT OU-2**
**ANOVA COMPARISON**
**RADIONUCLIDES IN SUBSURFACE SOIL, pCi/g**
**VADOSE ZONE**

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean(1) | Consider Further? |
| Americium 241 | 0 01 | 0 | 0 20 | 0 79 | No | Kruskal | 3 53 | 0 06 | N | N | Y(2) |
| Cesium 137 | 0 13 | 0 05 | 0 49 | 0 61 | No | Kruskal | 0 02 | 0 89 | N | N | N |
| Plutonium 239,240 | 0 01 | 0 005 | 1 65 | 7 16 | No | Kruskal | 9 18 | <0 01 | Y | N | Y |
| Radium 226 | 0 79 | 0 25 | 0 59 | 0 28 | No | Kruskal | 35 57 | <0 01 | Y | Y | N |
| Radium 228 | 1 38 | 0 31 | 1 39 | 0 44 | No | Kruskal | 0 005 | 0 94 | N | N | N |
| Strontium 89,90 | 0 37 | 0 27 | 0 22 | 0 17 | No | Kruskal | 10 62 | <0 01 | Y | Y | N |
| Strontium 90 | - | - | 0 46 | 0 17 | No | Kruskal | - | - | - | - | N |
| Tritium (pCi/L) | 168 | 103 1 | 225 | 132 | No | Kruskal | 20 05 | <0 01 | Y | N | Y |
| Uranium 233, 234 | 0 80 | 0 87 | 1 24 | 11 67 | No | Kruskal | 36 05 | <0 01 | Y | N | Y |
| Uranium 235 | 0 12 | 0 05 | 0 15 | 1 07 | No | Kruskal | 47 09 | <0 01 | Y | N | Y |
| Uranium 238 | 0 76 | 0 37 | 1 05 | 7 02 | No | Kruskal | 27 31 | <0 01 | Y | N | Y |

(1) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0 05) is not applicable

(2) Americium 241 is retained for further evaluation even though P>0 05 Background samples had only four positive results at 0 01 pCi/g.

- No data

# TABLE A-15
# ROCKY FLATS PLANT OU-2
# ANOVA COMPARISON
# METALS IN SURFACE SOIL, mg/kg

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test(1) | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean(2) | Consider Further? |
| Aluminum | 12,636 | 4,370 | 11,305 | 2,855 | Yes | ANOVA | 2.24 | 0.14 | N | Y | N |
| Antimony | 14 | 10 | ND | - | - | - | - | - | - | - | N |
| Arsenic | 6 | 2 | 4 | 1 | Yes | ANOVA | 27.99 | <0.01 | Y | Y | N |
| Barium | 196 | 93 | 126 | 27 | Yes | ANOVA | 21.06 | <0.01 | Y | Y | N |
| Beryllium | 2 | 0.89 | 2 | 0.84 | No | Kruskal | 3.98 | 0.05 | Y | Y | N |
| Cadmium | 1 | 0.9 | 2 | 0.84 | No | Kruskal | 5.68 | 0.02 | Y | N | Y |
| Cesium | 114 | 123 | ND | - | - | - | - | - | - | - | N |
| Chromium | 15 | 4 | 13 | 4 | No | Kruskal | 3.74 | 0.05 | N | Y | N |
| Cobalt | 8 | 4 | 7 | 2 | No | Kruskal | 0.02 | 0.90 | N | Y | N |
| Copper | 14 | 5 | 12 | 3 | Yes | ANOVA | 3.72 | 0.06 | N | Y | N |
| Lead | 37 | 7 | 37 | 12 | Yes | ANOVA | 0.05 | 0.82 | N | Y | N |
| Lithium | 11 | 3 | 9 | 4 | No | Kruskal | 7.27 | <0.01 | Y | Y | N |
| Molybedenum | 15 | 6 | 13 | 6 | No | Kruskal | 1.79 | 0.18 | N | Y | N |
| Manganese | 402 | 409 | 315 | 157 | No | Kruskal | 2.17 | 0.14 | N | Y | N |
| Mercury | 0.08 | 0.03 | ND | - | - | - | - | - | - | - | N |
| Nickel | 11 | 4 | 12 | 3 | Yes | ANOVA | 0.12 | 0.73 | N | N | N |
| Selenium | 0.59 | 0.20 | 0.88 | 0.22 | No | Kruskal | 15.81 | <0.01 | Y | N | Y |
| Silver | 3 | 2 | ND | - | - | - | - | - | - | - | N |
| Strontium | 39 | 19 | 39 | 19 | No | Kruskal | 0.01 | 0.92 | N | Y | N |
| Thallium | 0.76 | 0.33 | 0.98 | 0.11 | No | Kruskal | 11.18 | <0.01 | Y | N | Y |
| Tin | 30 | 12 | 40 | 14 | No | Kruskal | 10.19 | <0.01 | Y | N | Y |
| Vanadium | 32 | 8 | 30 | 8 | Yes | ANOVA | 0.93 | 0.34 | N | Y | N |
| Zinc | 56 | 16 | 53 | 11 | No | Kruskal | 1.07 | 0.30 | N | Y | N |

(1) ANOVA comparison is used on normally distributed data. The Kruskal analysis is used on non-normally distributed data.
(2) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference ($P<0.05$) is not applicable.
ND = not detected.
- no data

# TABLE A-16
# ROCKY FLATS PLANT OU-2
# ANOVA COMPARISON
# RADIONUCLIDES IN SURFACE SOIL, pCi/g

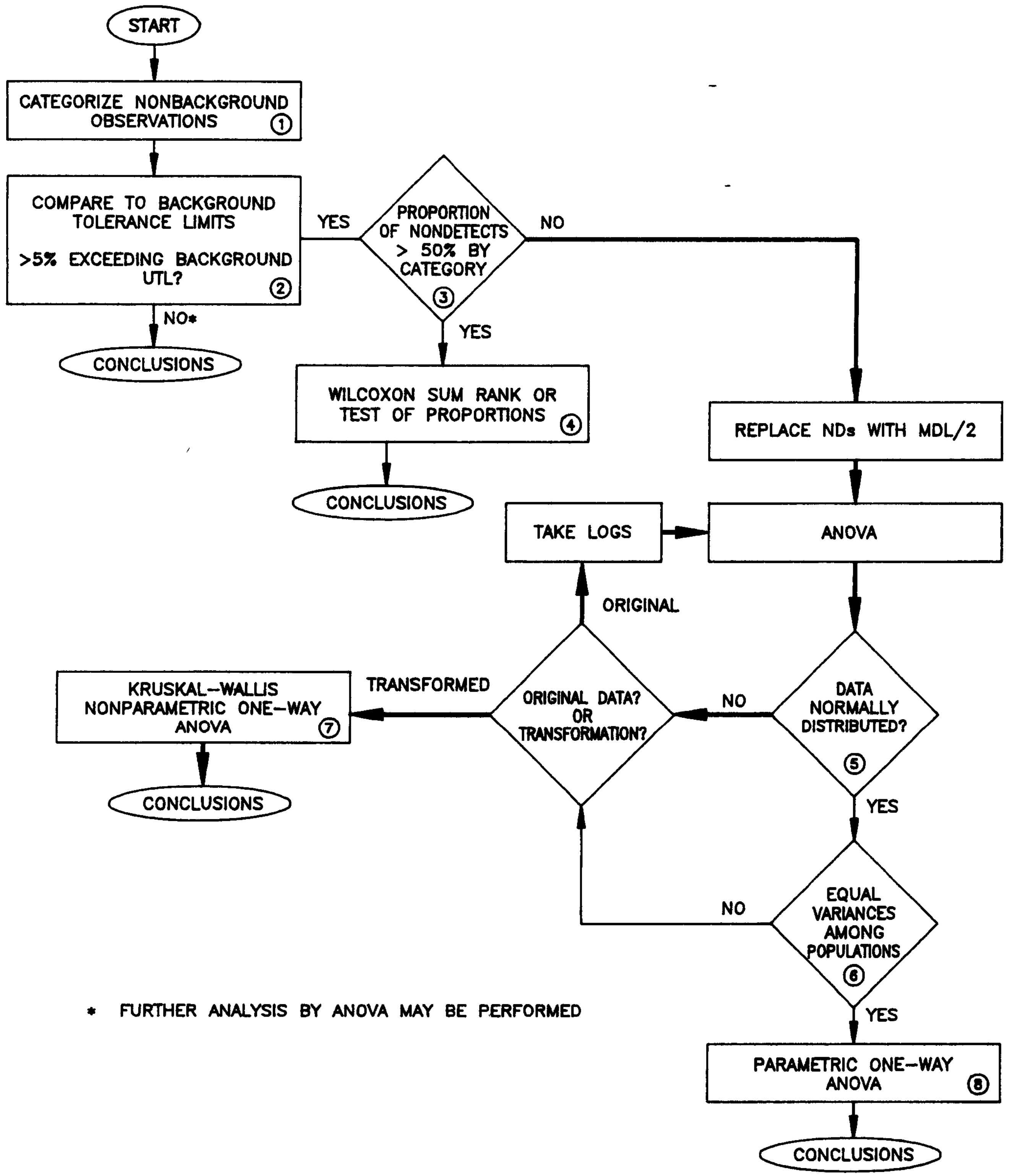
| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test(1) | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean(2) | Consider Further? |
| Americium 241 | 0 019 | 0 0096 | 15 71 | 27 25 | No | Kruskal | 33 18 | <0 01 | Y | N | Y |
| Cesium 137 | 1 39 | 0 48 | 0 81 | 0 48 | Yes | ANOVA | 13 01 | <0 01 | Y | Y | N |
| Plutonium 239 240 | 0 05 | 0 02 | 546 | 2,027 | No | - | (3) | - | - | N | Y |
| Radium 226 | 0 93 | 0 13 | 1 42 | 2 12 | No | Kruskal | 2 56 | 0 11 | N | N | N |
| Radium 228 | 2 14 | 0 53 | 2 05 | 0 56 | Yes | ANOVA | 0 19 | 0 66 | N | Y | N |
| Strontium 89,90 | 0 57 | 0 33 | 0 61 | 0 64 | Yes | ANOVA | 0 36 | 0 55 | N | N | N |
| Uranium 233,234 | 1 16 | 0 14 | 1 49 | 0 64 | No | Kruskal | 2 08 | 0 15 | N | N | N |
| Uranium 235 | 0 06 | 0 04 | 0 08 | 0 10 | No | Kruskal | 0 74 | 0 39 | N | N | N |
| Uranium 238 | 1 17 | 0 19 | 1 43 | 0 80 | No | Kruskal | 2 97 | 0 085 | N | N | N |
| Uranium 233 238,239 | - | - | 2 80 | 1 50 | - | - | - | - | - | - | Y |

(1) ANOVA comparison is used on normally distributed data. The Kruskal analysis is used on non-normally distributed data.

(2) If the background mean is equal to or higher than OU-2 data mean, a statistically significant difference (P<0 05) is not applicable

(3) Chi-square tests were not performed for plutonium 239,140 because OU-2 results clearly exceed background.

\- No background analysis for this analyte group




U.S DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO 2
PHASE II RFI/RI REPORT

SELECTION OF STATISTICAL METHOD FOR COMPARISON OF BACKGROUND AND NONBACKGROUND POPULATIONS

FIGURE A–1 JULY 1993

RF93CAL1

## APPENDIX B
## RISK-BASED EVALUATION OF INFREQUENTLY DETECTED CHEMICALS

### B.1 PURPOSE AND APPROACH

The chemicals of concern evaluated in a quantitative human health risk assessment are the subset of all site-related chemicals that are thought to pose the greatest potential risk to human health The determination that these chemicals may pose the greatest potential risk is generally based on an evaluation of the following three criteria

- The inherent toxicity of the chemical,
- The concentrations of the chemical found on-site, and
- The potential for human exposure to the chemical (e g, whether or not the chemical is widely distributed across the site or could readily migrate from the site)

In general, compounds found at low frequency (<5% of all samples) are not included as chemicals of concern because the potential for human exposure is limited However, all infrequently detected compounds were evaluated according to the procedures shown in Figure 2-1 so as not to neglect infrequently detected chemicals that could contribute significantly to risk if they were co-located with other potentially hazardous compounds at source areas or at locations where routine exposure could occur

This evaluation examines those organic chemicals that were initially excluded from the chemicals of concern based on low frequency of detection, using a health-based screening approach A screening evaluation was performed for all low-frequency chemicals for which toxicity values were available As a benchmark, it was assumed that any infrequently detected chemical whose maximum concentration was greater than 1000 times a risk-based concentration (RBC) based on a target hazard index (HI) of 1 0 or target excess cancer risk of $10^{-6}$ (1 in 1,000,000) warrants further evaluation The purpose is to identify those infrequently detected chemicals that may pose an unacceptable health risk (cancer or non-cancer) if chronic exposure were to occur These chemicals are retained for separate evaluation in the risk assessment as "special case" chemicals of concern Since they are not characteristic of contamination in OU-2, risk will be assessed separately at the locations where the special case chemicals are found

RBCs were calculated assuming a residential exposure scenario, using site-specific exposure assumptions, and using standard toxicity values (RfDs and SFs) established by EPA For surface soils and subsurface soils, multiple pathway exposure was assumed (ingestion, dermal contact, and inhalation of particulates) in calculating RBCs Exposure was evaluated for ingestion only for groundwater, since this was assumed to be the only major groundwater exposure route The parameters used to evaluate potential exposure (and to calculate intake factors) are presented in Tables B-1 through B-4 These parameters were presented in the Exposure Assessment Technical Memorandum No 5 (DOE 1993) Toxicity values were derived from IRIS (EPA 1993) and HEAST (EPA 1991a, 1992a), and are summarized in Tables 2-3 and 2-4 RBCs were then multiplied by 1000 to generate the screening concentrations for use in the evaluation

**Note on dermal absorption of organics from soil:**

The absorbed fraction (AB in Table B-3) is the estimated fraction of organic compounds adhered to soil particles that partitions to and is absorbed through skin Percent absorbed depends upon soil loading, organic carbon content of soil, contaminant concentration, duration of exposure, animal species used in the experiment, and whether the experiment is conducted in vitro or in vivo For purposes of this risk assessment, an upperbound estimate of absorption rate for organic compounds adhered to soil particles is assumed to be 10 percent These rates are based on experimental results using B(a)P in acetone or in crude oil, and adjusting the absorption rates for shorter exposure duration and the observed retarding effect of the soil medium[1] The experimental results are summarized in Table B-5, Percent Dermal Absorption of Neat Benzo(a)pyrene at 24 hours Absorption rates range from 3 to 51 percent at 24 hours The arithmetic mean absorption rate is 17 percent, and the 95 percent upper confidence limit (95% UCL) on the mean rate is 26 percent To adjust these experimental rates to account for site-specific exposure conditions, it is assumed that the exposed individual showers within 12 hours of exposure, and that absorption from soil is one-fifth that of the pure compound (Yang et al 1989, Wester et al 1990) Therefore, the 24-hour absorption rates of Neat B(a)P are adjusted by a factor of 0 5 for a 12-hour exposure and 0 2 for the soil matrix effect Resulting absorption rates are

1 In recent guidance on dermal exposure assessments (EPA 1992a), EPA has declined to recommend an absorption rate for B(a)P in soil because of the variability in experimental conditions and results and the difficulty in extrapolating from high soil loadings (e g., tens of mg/cm$^2$) under experimental conditions to lower loading (e g., 1 mg/cm$^2$) typical of human exposures (EPA 1992b) (B(a)P at concentrations of 1 and 10 mg/kg and soil loadings of 40 to 56 mg/cm$_2$, experimental results for percent absorbed at 24 hours ranges from 1 percent [Yang et al 1989] to 13 percent [Wester et al 1990])

17 x 0 5 x 0 2 = 1 7 percent (average)
26 x 0 5 x 0 2 = 2 6 percent (95% UCL)

Therefore, 10 percent is used as an upperbound estimate of dermal absorption rate of organic compounds adhered to soil

It should be noted that B(a)P is one of the more lipophilic of the polycyclic aromatic hydrocarbons, and, therefore, it may be absorbed at a higher rate than a number of other organic chemicals of concern Also, the use of dermal absorption values obtained in experimental animal studies will almost always result in a conservative (i e , higher) estimate of dermal absorption in humans (EPA 1992b) Therefore, the dermal absorption rate used in this analyses (10 percent) is concluded to be a conservative estimate of a reasonable maximum rate of dermal absorption of organic compounds from soil

## B.2 GROUNDWATER

Twenty-six VOCs and SVOCs were reported at low frequency (<5% detection) in groundwater samples Table B-6 presents a comparison of the maximum detected concentrations to the health-based screening criteria (both cancer and non-cancer) and presents the equations used to develop the screening concentrations Chemicals whose maximum detected concentration was greater than 1000 times either the cancer or non-cancer RBCs were retained for further evaluation as potential chemicals of concern Based on the comparison to screening-level concentrations, two chemicals, 1,2-dibromoethane and vinyl chloride, were identified as requiring further evaluation in the human health risk assessment as potential chemicals of concern (see Section 3 5)

## B.3 SOIL

Potentially site-related organic compounds detected at less than 5 percent frequency in subsurface soil samples and in surface soils are listed in Tables B-7 and B-8 Table B-7 (carcinogenic effects) presents a comparison of the maximum detected concentrations in subsurface and surface soils to the health-based screening criteria (carcinogens) and presents the equations used to develop the screening concentrations Table B-8 presents a similar comparison for non-carcinogenic effects

As with groundwater, chemicals whose maximum detected concentration was greater than 1000 times either the cancer or non-cancer risk-based screening concentration were retained for further evaluation as potential chemicals of concern Based on this evaluation, no infrequently detected chemicals found in surface or subsurface soils failed the screening evaluation (i e , none were identified as special case chemicals of concern)

## References


Cowherd, C , et al 1985 Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites EPA/600/8-85/002

Department of Energy (DOE) 1993 Technical Memorandum No 5 Exposure Scenarios Human Health Risk Assessment 903 Pad, Mound, and East Trenches Area, Operable Unit No 2 Draft Final Rocky Flats Plant Golden, CO

EPA 1989 Exposure Factors Handbook EPA/600/8-89/043

EPA 1991a Health Effects Assessment Summary Tables Annual FY-1991 OERR 9200 6-303

EPA 1991b Risk Assessment Guidance for Superfund Volume I, Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals) Interim OERR Publ No 9285 7-01B

EPA 1991c Human Health Evaluation Manual, Supplemental Guidance "Standard Default Exposure Factors" OSWER Directive 9285 6-03

EPA 1992a Health Effects Assessment Summary Tables Annual FY-1992 OERR 9200 6-303 March 1992

EPA 1992b Dermal Exposure Assessment Principles and Applications EPA/800/8-91/011B

EPA 1993 Integrated Risk Information System (IRIS) On-line database

Kao et al 1984 Toxicology and Applied Pharmacology 75 289-298

Kao et al 1985 Toxicology and Applied Pharmacology 81 502-516

Kao et al 1986 Toxicology and Applied Pharmacology 94 93-103

Sedman, R M 1989 The Development of Applied Action Levels for Soil Contact A Scenario for the Exposure of Humans to Soil in a Residential Setting Environmental Health Perspective 79 291-313

Wester et al 1990 Fundamentals of Applied Toxicology 15 510-516

Yang et al 1986 Toxicology and Industrial Health 2 409-416

Yang et al 1989 Bulletin of Environmental Contaminants and Toxicology 43 207-214

**TABLE B-1**
**ROCKY FLATS PLANT OU-2**
**UHSU GROUNDWATER INGESTION**
**HYPOTHETICAL FUTURE ON-SITE RESIDENT**

$$\text{Intake Factor} = \frac{IR \times EF \times ED \times FI}{BW \times AT}$$

| | Parameter | RME |
|---|---|---|
| IR | Intake rate (l/day)[1] | 2 0 |
| EF | Exposure frequency (days/year)[1] | 350 |
| ED | Exposure duration (years)[1] | 30 |
| FI | Fraction ingested from contaminated source | 1 0 |
| BW | Body weight (kg) | 70 |
| AT | Averaging time (days) | |
| | Noncarcinogenic | 10,950 |
| | Carcinogenic | 25,550 |
| IF | Intake Factor (L/kg-day) | |
| | Noncarcinogenic | 0 027 |
| | Carcinogenic | 0 0117 |

(1) Source EPA 1991c

## TABLE B-2
## ROCKY FLATS PLANT OU-2
## SOIL INGESTION
## CURRENT OFF-SITE RESIDENT (ADULT AND CHILD)[1]

Noncarcinogenic

$$\text{Intake Factor} = \left[\frac{(200\ mg/day \times 350\ day/yr \times 6\ yr)}{15\ kg \times 365\ day/yr} + \frac{(100\ mg/day \times 350\ day/yr \times 24\ yr)}{70\ kg \times 365\ day/yr}\right] \times 0\ 5 \times 10^{-6}\ kg/mg/30\ yr$$

Carcinogenic

$$\text{Intake Factor} = \left[\frac{(200\ mg/day \times 350\ day/yr \times 6\ yr)}{15\ kg \times 365\ day/yr} + \frac{(100\ mg/day \times 350\ day/yr \times 24\ yr)}{70\ kg \times 365\ day/yr}\right] \times 0\ 5 \times 10^{-6}\ kg/mg/70\ yr$$

| | Parameter | RME | |
|---|---|---|---|
| | | Adult | Child |
| IR | Ingestion rate (mg/day)[1] | 100 | 200 |
| FI | Fraction ingested from contaminated source[2] | 0 5 | 0 5 |
| ME | Matrix effect[3] | 1 0 | 1 0 |
| EF | Exposure frequency (days/year)[4] | 350 | 350 |
| ED | Exposure duration (years)[5] | 24 | 6 |
| CF | Conversion factor (kg/mg) | $10^{-6}$ | $10^{-6}$ |
| BW | Body weight (kg) | 70 | 15 |
| AT | Averaging time (days) | | |
| | Noncarcinogenic | 10,950 | |
| | Carcinogenic | 25,550 | |
| IF | Intake Factor (kg/kg-day) | | |
| | Noncarcinogenic | $1\ 8 \times 10^{-6}$ | |
| | Carcinogenic | $7\ 8 \times 10^{-6}$ | |

(1) The calculation of a 30-year residential exposure to soil is divided into two parts First, a six-year exposure duration is evaluated for young children, and this accounts for the period of highest soil ingestion (200 mg/day) and lowest body weight (15 kg) Second, a 24-year exposure duration is assessed for older children and adults by using a lower soil ingestion rate (100 mg/day) and an adult body weight (70 kg) (EPA 1991c)

(2) The FI assumes that 50 percent of the soil ingested daily is from the contaminated source

(3) The matrix effect describes the reduced availability due to adsorption of chemicals to soil or food compared to the same dose administered orally in solution Therefore, the soil matrix has the effect of reducing the intake of the compound A matrix effect of 1 0 (100 percent absorption) is used as a conservative value for screening purposes

(4) EPA 1991c

(5) Thirty-year residential exposure EPA 1991c

**TABLE B-3**
**ROCKY FLATS PLANT OU-2**
**DERMAL CONTACT WITH SURFACE SOIL**
**CURRENT OFF-SITE RESIDENT**

$$\text{Intake Factor} = \frac{SA \times AB \times AF \times FC \times EF \times ED \times CF}{BW \times AT}$$

| | Parameter | RME |
|---|---|---|
| SA | Surface area ($cm^2$)[1] | 2,910 |
| AB | Absorption factor[2] | 0 1 |
| AF | Adherence factor ($mg/cm^2$)[3] | 0 5 |
| FC | Fraction contacted from contaminated source[4] | 0 5 |
| EF | Exposure frequency (days/year)[5] | 350 |
| ED | Exposure duration (years)[6] | 30 |
| CF | Conversion factor (kg/mg) | $10^{-6}$ |
| BW | Body weight (kg) | 70 |
| AT | Averaging time (days) | |
| | Noncarcinogenic | 10,950 |
| | Carcinogenic | 25,550 |
| IF | Intake Factor (kg/kg-day) | |
| | Noncarcinogenic | $1\ 0 \times 10^{-6}$ |
| | Carcinogenic | $4\ 3 \times 10^{-7}$ |

(1) The surface area is equivalent to face, forearms, and hands, or 15 percent of total body surface (EPA 1989)

(2) Dermal absorption of metals from a soil matrix is considered negligible For screening purposes, the absorption factor for semivolatiles, volatiles, and other organics is assumed to be 10 percent (see Table B-8)

(3) Source Sedman 1989

(4) The FC assumes that residents are at home for 16 hours per day and are at work, school, or other locations for 8 hours per day

(5) Assumes that residents take 15 days per year vacation (EPA 1991c)

(6) Source EPA 1991c

**TABLE B-4**
**ROCKY FLATS PLANT OU-2**
**INHALATION OF PARTICULATES**
**CURRENT OFF-SITE RESIDENT**

$$\text{Intake Factor} = \frac{IR \times ET \times EF \times ED \times DF}{BW \times AT}$$

| | Parameter | RME |
|---|---|---|
| IR = | Inhalation rate ($m^3$/hr)(1) | 0 83 |
| ET = | Exposure time (hours/day) | 24 |
| EF = | Exposure frequency (days/year)(2) | 350 |
| ED = | Exposure duration (years)(2) | 30 |
| DF = | Deposition factor(3) | 0 75 |
| BW = | Body weight (kg) | 70 |
| AT = | Averaging time (days) | |
| | Noncarcinogenic | 10,950 |
| | Carcinogenic | 25,550 |
| IF | Intake Factor ($m^3$/kg-day) | |
| | Noncarcinogenic | $2 0 \times 10^{1}$ |
| | Carcinogenic | $8 8 \times 10^{2}$ |

(1) Equivalent to 20 $m^3$/day (EPA 1991c)
(2) EPA 1991c
(3) Seventy-five percent of inhaled particles are deposited and remain in the lung, it is assumed that all chemicals in that fraction are absorbed (Cowherd 1985)

## TABLE B-5
## ROCKY FLATS PLANT OU-2
## PERCENT DERMAL ABSORPTION OF BENZO(A)PYRENE AT 24 HOURS

| Source[1] | % BaP Absorbed at 24 hr | Preparation | Vehicle | Dose |
|---|---|---|---|---|
| Yang et al 1986 | 6 | Rat in vivo | Acetone | 9-10 $ug/cm^2$ |
| | 17 | Rat in vitro | Acetone | 9-10 $ug/cm^2$ |
| Yang et al 1989 | 6 | Rat in vivo | 1 ppm BaP in crude oil | 90 $ug/cm^2$ |
| | 12 | Rat in vitro | 1 ppm BaP in crude oil | 90 $ug/cm^2$ |
| Kao et al 1984 | 24 | Mouse in vitro | Acetone | 1 $ug/cm^2$ |
| Kao et al 1985 | 3 | Human in vitro | Acetone | 2 $ug/cm^2$ |
| Kao et al 1988 | 10 | Mice in vitro | Acetone | 2 5 $ug/cm^2$ |
| Wester 1990 | 24 | Human in vitro | Acetone | 10 ppm |
| | 51 | Rhesus monkey in vivo | Acetone | 10 ppm |
| Average % Absorbed | 17 | | | |
| 95% UCL % Absorbed | 26 | | | |


Kao et al 1984 Toxicology and Applied Pharmacology 75 289-298
Kao et al 1985 Toxicology and Applied Pharmacology 81 502-516
Kao et al 1986 Toxicology and Applied Pharmacology 94 93-103
Yang et al 1986 Toxicology and Industrial Health 2 409-416
Yang et al 1989 Bulletin of Environmental Contaminants and Toxicology 43 207-214
Wester et al 1990 Fundamentals of Applied Toxicology 15 510-516


(1) The cited studies are from the references cited in EPA 1992 Dermal Exposure Assessment Principles and Applications (EPA/800/8-91/011B) Studies not cited in this table include those conducted in previously frozen tissue and Sanders et al 1984 (in vivo percutaneous absorption of BaP in mouse) The latter was excluded because mouse skin has been shown to be 2 5 to 5 times more permeable than skin of other species, including humans (Kao et al 1985, as cited in EPA 1992 Dermal Exposure Assessment Principles and Applications)

## TABLE B-6
## COMPARISON TO RISK-BASED SCREENING CONCENTRATIONS
## GROUNDWATER COMPOUNDS AT LESS THAN 5% FREQUENCY OF DETECTION
## CARCINOGENIC AND NON-CARCINOGENIC EFFECTS

**Equations.** Cs-c = Risk / (IForal-c x SForal)
Cs-nc = (HI x RfDoral) / IForal-nc

**Where**

Cs-c = Cancer Risk-Based Screening Concentration
Cs-nc = Noncancer Risk-Based Screening Concentration
Risk = Target Cancer Risk Level of 1 E-6 (1 in 1 million)
HI = Target Hazard Index = 1
IForal-c = Oral Intake Factor for Carcinogens (Table B-1)
IForal-nc = Oral Intake Factor for Noncarcinogens (Table B-1)
SForal = Oral Slope Factor
RfDoral = Oral Reference Dose
RBC-c = Risk-based concentration at 1E-6 target excess cancer risk
RBC-nc = Risk based concentration at HI = 1

| CHEMICAL | SForal (mg/kg-d)^-1 | RfDoral mg/kg-d | IForal-c L/kg-d | RBC-c mg/L | IForal-nc L/kg-d | RBC-nc mg/L | CS-c 1000 x RBC-c | Cs-nc 1000 x RBC-nc | Maximum Conc. mg/L | Maximum Conc. > Cs |
|---|---|---|---|---|---|---|---|---|---|---|
| 1,1,2,2-tetrachloroethane | 2.0E-01 | - | 1.17E-02 | 4.3E-04 | 2.7E-02 | - | 4.3E-01 | - | 1.80E-01 | NO |
| 1,1,2-trichloroethane | 5.7E-02 | 4.0E-03 | 1.17E-02 | 1.5E-03 | 2.7E-02 | 1.5E-01 | 1.5E+00 | 1.5E+02 | 2.10E-02 | NO |
| 1,2,3-trichloropropane | - | 6.0E-03 | 1.17E-02 | - | 2.7E-02 | 2.2E-01 | - | 2.2E+02 | 2.00E-03 | NO |
| 1,2,4-trichlorobenzene | - | 1.0E-02 | 1.17E-02 | - | 2.7E-02 | 3.6E-01 | - | 3.6E+02 | 2.00E-03 | NO |
| 1,2-dibromoethane | 8.5E+01 | - | 1.17E-02 | 1.0E-06 | 2.7E-02 | - | 1.0E-03 | - | 1.30E-02 | YES |
| 1,2-dichlorobenzene | - | 9.0E-02 | 1.17E-02 | - | 2.7E-02 | 3.3E+00 | - | 3.3E+03 | 1.00E-04 | NO |
| 1,2-dichloroethane | 9.1E-02 | - | 1.17E-02 | 9.4E-04 | 2.7E-02 | - | 9.4E-01 | - | 7.30E-03 | NO |
| 1,2-dimethylbenzene (o-xylene) | - | 2.0E+00 | 1.17E-02 | - | 2.7E-02 | 7.3E+01 | - | 7.3E+04 | 2.00E-04 | NO |
| 1,3-dimethylbenzene (m-xylene) | - | 2.0E+00 | 1.17E-02 | - | 2.7E-02 | 7.3E+01 | - | 7.3E+04 | 3.00E-04 | NO |
| 1,4-dichlorobenzene | 2.4E-02 | - | 1.17E-02 | 3.6E-03 | 2.7E-02 | - | 3.6E+00 | - | 3.00E-04 | NO |
| 4-methyl-2-pentanone | - | 5.0E-02 | 1.17E-02 | - | 2.7E-02 | 1.8E+00 | - | 1.8E+03 | 1.00E-02 | NO |
| bromoform | 7.9E-03 | 2.0E-02 | 1.17E-02 | 1.1E-02 | 2.7E-02 | 7.3E-01 | 1.1E+01 | 7.3E+02 | 6.00E-03 | NO |
| chlorobenzene | - | 2.0E-02 | 1.17E-02 | - | 2.7E-02 | 7.3E-01 | - | 7.3E+02 | 2.00E-02 | NO |
| chloromethane | 1.3E-02 | - | 1.17E-02 | 6.6E-03 | 2.7E-02 | - | 6.6E+00 | - | 5.00E-03 | NO |
| cis-1,3-dichloropropene | - | 3.0E-04 | 1.17E-02 | - | 2.7E-02 | 1.1E-02 | - | 1.1E+01 | 1.70E+00 | NO |
| dibromomethane | - | 1.0E-02 | 1.17E-02 | - | 2.7E-02 | 3.6E-01 | - | 3.6E+02 | 1.70E+00 | NO |
| dichlorodifluoromethane | - | 2.0E-01 | 1.17E-02 | - | 2.7E-02 | 7.3E+00 | - | 7.3E+03 | 6.00E-04 | NO |
| ethylbenzene | - | 1.0E-01 | 1.17E-02 | - | 2.7E-02 | 3.6E+00 | - | 3.6E+03 | 2.00E-02 | NO |
| hexachlorobutadiene | 7.8E-02 | - | 1.17E-02 | 1.1E-03 | 2.7E-02 | - | 1.1E+00 | - | 1.20E-03 | NO |
| o-chlorotoluene | - | 2.0E-02 | 1.17E-02 | - | 2.7E-02 | 7.3E-01 | - | 7.3E+02 | 3.00E-03 | NO |
| 1,2-dibromo-3-chloropropane | 1.4E+00 | - | 1.17E-02 | 6.1E-05 | 2.7E-02 | - | 6.1E-02 | - | 4.20E-03 | NO |
| styrene | - | 2.0E-01 | 1.17E-02 | - | 2.7E-02 | 7.3E+00 | - | 7.3E+03 | 1.00E-02 | NO |
| vinyl chloride | 1.9E+00 | - | 1.17E-02 | 4.5E-05 | 2.7E-02 | - | 4.5E-02 | - | 8.60E-01 | YES |
| di-n-butylphthalate | - | 1.0E+01 | 1.17E-02 | - | 2.7E-02 | 3.6E+02 | - | 3.6E+05 | 3.00E-03 | NO |

## TABLE B-7
## COMPARISON TO RISK-BASED SCREENING CONCENTRATIONS
## SOIL COMPOUNDS AT LESS THAN 5% FREQUENCY
## CARCINOGENIC EFFECTS

**Equation** Cs = Risk / [((IForal +IFderm) x SF oral)+ (IFinh x SF inh)]

**Where**

Cs = Screening concentration in soil (mg/kg)
Risk = Target cancer risk level
SF oral = Slope Factor for oral route
SF inh = Slope Factor for inhalation exposure route
IForal = Oral Intake Factor (Table B 2)

IFderm = Dermal Exposure Intake Factor (Table B-3)
IFinh = Inhalation Exposure Intake Factor (Table B-4), incorporating PM10 air concentration
PM Air = 37 µg/m^3 (Site-specific, assumed 100% PM10)
RBC = Risk-based screening concentration at 1 E-6 target cancer risk level

Target Risk = 1.0E-06 1.0E-03

| CHEMICAL | IFderm kg/kg-d | IForal kg/kg-d | PM Air Conc. kg/m^3 | PM IFinh kg/kg-d | SF oral (mg/kg-day)^-1 | SF inh (mg/kg-day)^-1 | RBC (mg/kg) | Cs (1000 X RBC) (mg/kg) | Maximum Conc. (mg/kg) | Maximum Conc. > Cs? |
|---|---|---|---|---|---|---|---|---|---|---|
| **Subsurface Soil** | | | | | | | | | | |
| **benzene** | 4.2E-07 | 7.8E-07 | 0 | 0 | 2.9E-02 | 2.9E-02 | 2.9E+01 | 2.9E+04 | 1.2E-02 | NO |
| **chloroform** | 4.2E-07 | 7.8E-07 | 0 | 0 | 6.1E-03 | 8.0E-02 | 1.4E+02 | 1.4E+05 | 8.8E+00 | NO |
| **carbon tetrachloride** | 4.2E-07 | 7.8E-07 | 0 | 0 | 1.3E-01 | 5.3E-02 | 6.4E+00 | 6.4E+03 | 1.4E+02 | NO |
| **pentachlorophenol** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 1.2E-02 | | 6.9E+01 | 6.9E+04 | 9.5E-02 | NO |
| **1,4-dichlorobenzene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 2.4E-02 | | 3.5E+01 | 3.5E+04 | 4.3E-02 | NO |
| **benzo(a)pyrene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 5.8E+00 | 6.1E+00 | 1.4E-01 | 1.4E+02 | 4.8E-01 | NO |
| **chrysene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 5.8E-02 | | 1.4E+01 | 1.4E+04 | 4.2E-01 | NO |
| **benzo(a)anthracene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 5.8E-01 | | 1.4E+00 | 1.4E+03 | 5.3E-01 | NO |
| **benzo(b)fluoranthene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 5.8E-01 | | 1.4E+00 | 1.4E+03 | 8.2E-01 | NO |
| **hexachlorobutadiene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 7.8E-02 | 7.8E-02 | 1.1E+01 | 1.1E+04 | 1.7E-01 | NO |
| **hexachloroethane** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 1.4E-02 | 1.4E-02 | 5.9E+01 | 5.9E+04 | 1.1E+00 | NO |
| **indeno(1,2,3-c,d)pyrene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 5.8E-01 | | 1.4E+00 | 1.4E+03 | 3.3E-01 | NO |
| **4,4 -DDT** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 3.4E-01 | 3.4E-01 | 2.4E+00 | 2.4E+03 | 1.4E-01 | NO |
| **Aroclor 1254** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 7.7E+00 | | 1.1E-01 | 1.1E+02 | 8.9E+00 | NO |
| | | | | | | | | | | |
| **Surface Soil** | | | | | | | | | | |
| **Aroclor 1254** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 7.7E+00 | | 1.1E-01 | 1.1E+02 | 9.7E-01 | NO |
| **Aroclor 1260** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 7.7E+00 | | 1.1E-01 | 1.1E+02 | 6.6E-01 | NO |
| **4,4'-DDT** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 3.4E-01 | 3.4E-01 | 2.4E+00 | 2.4E+03 | 2.6E-02 | NO |
| **benzo(k)fluoranthene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 5.8E-01 | - | 1.4E+00 | 1.4E+03 | 7.6E-02 | NO |
| **indeno(1,2,3-cd)pyrene** | 4.2E-07 | 7.8E-07 | 3.7E-08 | 3.3E-09 | 5.8E-01 | | 1.4E+00 | 1.4E+03 | 8.3E-02 | NO |

# TABLE B-8
## COMPARISON TO RISK-BASED SCREENING CONCENTRATIONS
## SOIL COMPOUNDS AT LESS THAN 5% FREQUENCY
## NON-CARCINOGENIC EFFECTS

**Equation** Cs = (HI) / [((IForal + IFderm) / RfD oral) + (IFinh / RfD inh)]

**Where**
Cs = Screening concentration in soil (mg/kg)
HI = Target Hazard Index
IForal = Oral Intake Factor
IFderm = Dermal Exposure Intake Factor
IFinh = Inhalation Exposure Intake Factor

RfD oral = Oral Reference Dose, mg/kday
RfD inh = Inhalation Reference Dose, mg/kg-day
PM AIR = 37g/m^3 (Site-Specific value assumed to be 100% PM10)
RBC = Risk-based screening concentration at 1 0 target HI

| | | | | | Target HI = | | 1 | 1000 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CHEMICALS | IFderm kg/kg-d | IForal kg/kg-d | PM Air Conc. kg/m^3 | PM IFinh kg/kg-d | Oral RfD | Inhalation RfD | RBC (mg/kg) | Cs (1000 X RBC) (mg/kg) | Maximum Conc. (mg/kg) | Maximum Conc. > Cs? |
| Subsurface Soil | | | | | | | | | | |
| chloroethane | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | | 3 | 3 95E+08 | 3 95E+11 | 5 00E-02 | NO |
| chloroform | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 1 00E-02 | | 3 57E+03 | 3 57E+06 | 8 80E+00 | NO |
| cis-1,3-dichloropropene | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 3 00E-04 | 5 00E-03 | 1 07E+02 | 1 07E+05 | 6 00E-03 | NO |
| ethylbenzene | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 1 00E-01 | 3 00E-01 | 3 57E+04 | 3 57E+07 | 7 80E-01 | NO |
| styrene | 1 00E-06 | 1.80E-06 | 3 70E-08 | 7 59E-09 | 2.00E-01 | 3 00E-01 | 7 13E+04 | 7 13E+07 | 1 70E-02 | NO |
| carbon tetrachloride | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 7 00E-04 | | 2 50E+02 | 2.50E+05 | 1 40E+02 | NO |
| 1,2-dichloroethene | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 9 00E-03 | | 3 21E+03 | 3 21E+06 | 9 00E-02 | NO |
| pentachlorophenol | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 3 00E-02 | | 1 07E+04 | 1 07E+07 | 9 50E-02 | NO |
| fluoranthene | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 4 00E-02 | | 1 43E+04 | 1 43E+07 | 1 00E+00 | NO |
| pyrene | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 3 00E-02 | | 1 07E+04 | 1 07E+07 | 1 30E+00 | NO |
| 1,4-dichlorobenzene | 1 00E-06 | 1 80E-06 | 3.70E-08 | 7 59E-09 | | 2.00E-01 | 2 64E+07 | 2.64E+10 | 4 30E-02 | NO |
| acenaphthene | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 6.00E-02 | | 2.14E+04 | 2.14E+07 | 2 80E-01 | NO |
| di-n-octyl phthalate | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 2.00E-02 | | 7 14E+03 | 7 14E+06 | 2.60E-01 | NO |
| naphthalene | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 4 00E-02 | | 1 43E+04 | 1 43E+07 | 2 00E+00 | NO |
| benzoic acid | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 4 00E+00 | | 1 43E+06 | 1 43E+09 | 4 00E-01 | NO |
| anthracene | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 3 00E-01 | | 1 07E+05 | 1 07E+08 | 2.60E-01 | NO |
| butyl benzyl phthalate | 1 00E-06 | 1.80E-06 | 3 70E-08 | 7 59E-09 | 2.00E-01 | | 7 14E+04 | 7 14E+07 | 5 20E-01 | NO |
| diethyl phthalate | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 8 00E-01 | | 2 86E+05 | 2.86E+08 | 5 20E-02 | NO |
| hexachloroethane | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 1 00E-03 | | 3 57E+02 | 3 57E+05 | 1 10E+00 | NO |
| 4,4'-DDT | 1 00E-06 | 1 80E-06 | 3 70E-08 | 7 59E-09 | 5 00E-04 | | 1 79E+02 | 1 79E+05 | 1 40E-01 | NO |

# OU-2 DOMESTIC WATER SUPPLY SIMULATIONS

**The results of computer simulations of domestic water production capabilities from subsurface units beneath OU-2 at the Rocky Flats Plant, Golden, Colorado**

This work was performed by the Earth Resources Division
for the Remediation Programs Division
in support of risk analysis studies.

September 10, 1992

## INTRODUCTION

To investigate the water production capabilities of the near surface hydrostratigraphic units beneath Operable-unit 2 at the Rocky Flats Plant several transient pumping computer simulations were performed. These simulations were designed to determine whether these units could produce sufficient water to supply a hypothetical four-member household. A daily pumping requirement of 240 gallons per day (gpd) was assumed based on a daily water requirement of 60 gallons per person

Independent simulations were performed for three different hydrostratigraphic units Models were constructed for the Rocky Flats Alluvium, hillslope colluvial materials, and an unconfined Arapahoe sandstone unit representing the #1 sandstone beneath OU-2. The Rocky Flats Alluvium and hillslope colluvial materials were not considered reliable water sources but were included in the simulations since they comprise the upper-most hydrostratigraphic units and have been impacted by plant activities. The Arapahoe sandstone unit was included because it was considered to be the best prospect for producing water from the Arapahoe Formation. The claystones of the Arapahoe formation were not considered good prospects for water and as such were not modeled.

## METHOD

Simulations were performed using the USGS MODFLOW groundwater flow simulation package (McDonald and Harbaugh, 1988). Input parameters common to all simulations are listed in table 1. Separate simulations were done for the Rocky Flats Alluvium, hillslope colluvium and the Arapahoe sand unit. A listing of the input parameters for these simulations are given in tables 2, 3, and 4. Simulations were run using a daily time-frame until the pumping-well grid cell went dry or the end of the simulation (365 days) was reached.

Each day of the transient simulation was divided into two periods and each period was divided into two timesteps. The first 2.7 hours of each day was used as a pumping period. It was assumed that the household maintained water storage capabilities and that this pumping period was used to replenish the water storage system. A pumping rate of 1.5 gpm was used. This rate is below the 3-5 gpm rate commonly used for domestic wells and as such is conservative. The pumping period was based on the total daily water requirement (240 gal.) and the pumping rate (1.5 gpm)

$$240 \text{ gal}/(1.5 \text{ gal/min} \cdot 60 \text{ min/hr}) = 2.7 \text{ hrs}$$

The remaining 21 3 hours of each day allowed water level recovery to take place.

The pumping well was located at the center of the grid cell array. A variable grid spacing ranging from 5 feet at the well to 50 feet at the boundaries was used to provide realistic drawdown conditions near the well. The grid spacing for each scenario are given in tables 2, 3, and 4.

Boundary conditions were either constant head (equal to the initial head) or no-flow depending on the scenario. For the Rocky Flats Alluvium and hillslope colluvium scenarios constant head boundaries were used at all boundaries. For the Arapahoe sandstone simulation the modeling grid was intended to represent a discontinuous channel sand deposit. To implement this configuration no-flow boundaries were placed along two parallel sides of the grid with constant head boundaries along the other two sides.

Table 1
Modeling parameters common to all scenarios

| PARAMETER | VALUE | SOURCE |
|---|---|---|
| Water Requirement | 240 gpd | Based on 60 gal/person/day |
| Pumping Rate | 1 5 gpm | Assumed |
| Pumping Time per Day | 2.7 hrs | Based on pumping rate |
| X to Y Anisotropy | 1 (isotropic) | Assumed |

## ROCKY FLATS ALLUVIUM SCENARIO

Scenario specific parameters for the Rocky Flats Alluvium simulation are given in table 2. The modeling grid for this scenario consisted of a 19 by 19 grid cell array with the pumping well at the center of the grid and constant head boundaries (equal to the initial head) along each edge of the grid. The grid spacing in feet for the x and y directions increased from the well as follows $5_{well}$-7-10-15-25-35-50-50-50-$50_{boundary}$ (see figure 1). The hydraulic conductivity value comes from the recent OU-2 aquifer pump testing program. The value used represents the geometric mean of the results from two test locations. The specific yield came from lab analyses of core samples and example values from the literature for fine-grained materials (Fetter, 1980, pg. 68). The initial saturated thickness represents the historical average for well 1787 which is within OU-2. During initial pump test planning this well was observed to have the greatest alluvial saturated thickness and therefore should represent the most reliable OU-2 alluvial water source.

Table 2
Modeling Parameters for Rocky Flats Alluvium

| PARAMETER | VALUE | SOURCE |
|---|---|---|
| Hydraulic Conductivity | 1.6 ft/day | OU-2 pumping test |
| Specific Yield | 0.10 | Lab analyses/literature |
| Grid Spacing (variable) | from 5 to 50 ft | Assumed |
| Hydrogeologic Unit Condition | Unconfined | On-site observation |
| Initial Saturated Thickness | 7.2 ft | Observation wells |
| Boundary Conditions | Constant head | Assumed |

Results

For the Rocky Flats Alluvium scenario the pumping-well grid cell went dry within one to two hours after pumping started on the first day of the simulation. These results are consistent with the low pumping rates (0.3 - 0.056 gpm) required during field pump testing to avoid excessive drawdown.

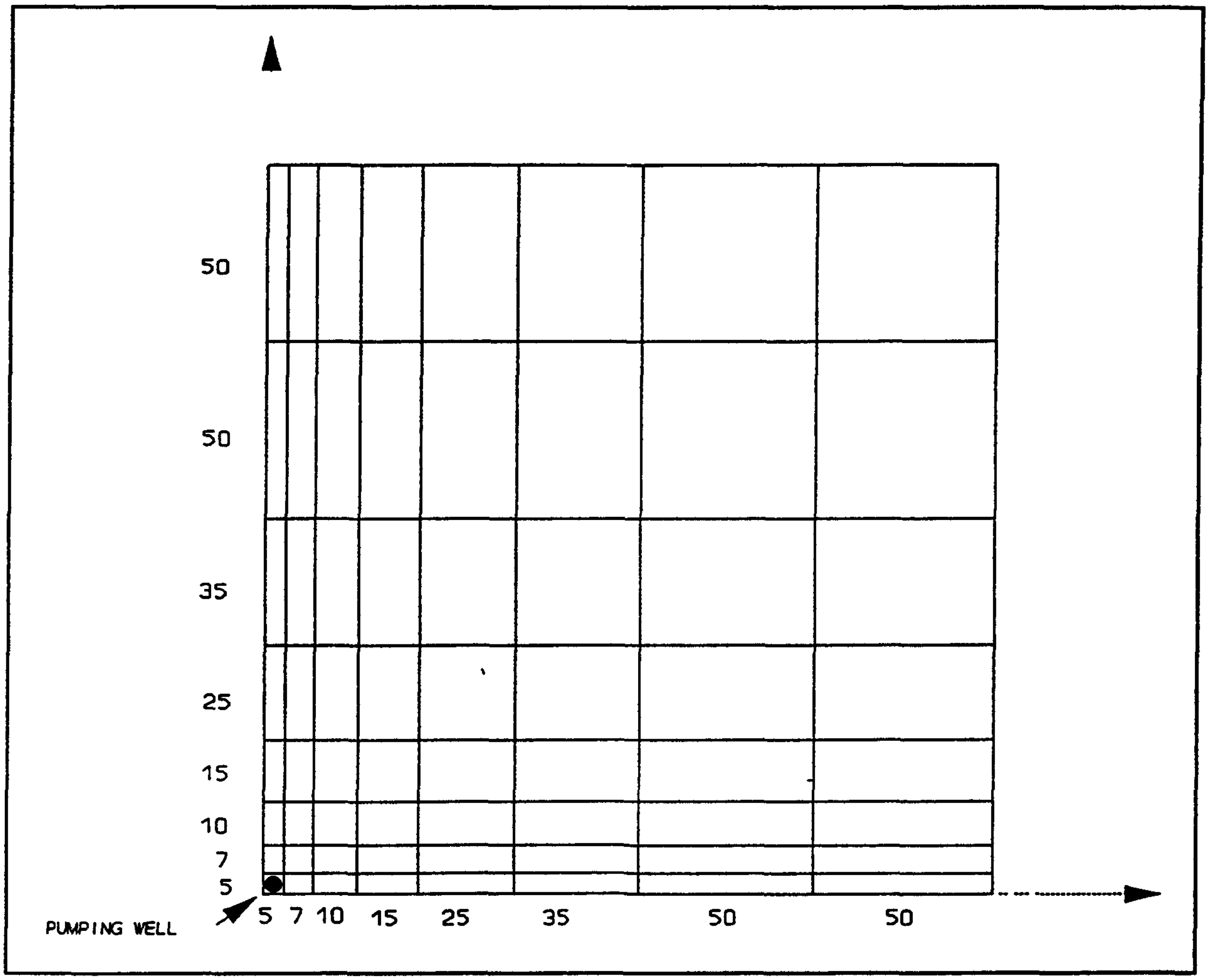



Figure 1 Figure shows 1/4 (upper right-hand quadrant) of an example model grid In model well is at center of grid Grid spacings in feet The number of grid nodes for each model may differ, but grid spacings are similar Not to scale.

## HILLSLOPE COLLUVIUM SCENARIO

Scenario specific parameters for the hillslope colluvium simulation are given in table 3. The modeling grid for this scenario consisted of a 19 by 19 grid cell array with the pumping well at the center of the grid and constant head boundaries (equal to the initial head) along each edge of the grid. The grid spacing in feet in the x and y directions increased from the well as follows $5_{well}$-7-10-15-25-35-50-50-50-$50_{boundary}$ (see figure 1). Because there were no hydraulic conductivity values for OU-2 colluvium, data from slug-tests in colluvial material from OU-1 were used. These values should be representative of conditions in OU-2 since OU-1 and OU-2 are physically adjacent to each other. The specific yield came from lab analyses of core samples and example values from the literature for fine-grained materials (Fetter, 1980, pg. 68). The initial saturated thickness represents the average for well 0687 which is within OU-2. Comparisons of water level data indicate this well has historically had relatively large saturated thicknesses and would therefore represent conditions most promising for OU-2 colluvial water production.

Table 3
Modeling Parameters for Hillslope Colluvium

| PARAMETER | VALUE | SOURCE |
|---|---|---|
| Hydraulic Conductivity | 0.17 ft/day | OU-1 field testing |
| Specific Yield | 0.10 | Lab analyses/literature |
| Grid Spacing (variable) | from 5 to 50 ft | Assumed |
| Hydrogeologic Unit Character | Unconfined | On-site observation |
| Initial Saturated Thickness | 3.6 ft | Observation wells |
| Boundary Conditions | Constant head | Assumed |

### Results

For the hillslope colluvium scenario the pumping-well grid cell went dry within one hour after pumping started on the first day of the simulation. This is consistent with the low hydraulic conductivity and small saturated thickness observed for colluvial materials.

## ARAPAHOE SANDSTONE SCENARIO

Scenario specific parameters for the Arapahoe Sandstone simulation are given in table 4. The modeling grid for this scenario consisted of a grid cell array of 23 rows by 31 columns with the pumping well at the center of the grid. The rectangular shape of the modeling grid represents the elongate physical shape of the sandstone unit as reconstructed from borehole information. Constant head boundaries (equal to the initial head) were used along the first and last columns of the grid with no-flow boundaries set along the other two edges. The grid spacing in feet in the x and y directions increased from the well as follows $5_{well}$-7-10-15-25-35-50-50- ... $-50_{boundary}$ (see figure 1). The hydraulic conductivity value came from OU-2 aquifer pump testing. *The specific yield is assumed equal to the effective porosity computed for* this sandstone from the OU-2 tracer test program. The initial saturated thickness represents the historic average for well 3687 which was included in the OU-2 aquifer test program for the #1 Arapahoe Sandstone.

Table 4
Modeling Parameters for Arapahoe Sandstone

| PARAMETER | VALUE | SOURCE |
|---|---|---|
| Hydraulic Conductivity | 1.1 ft/day | OU-2 field testing |
| Specific Yield | 0 12 | OU-2 tracer testing |
| Grid Spacing (variable) | from 5 to 50 ft | Assumed |
| Hydrogeologic Unit Condition | Unconfined | On-site observation |
| Initial Saturated Thickness | 33.7 ft | Observation wells |
| Boundary Conditions | Constant head & No flow | Assumed |

### Results

For the Arapahoe Sandstone scenario the pumping well was able to meet the water requirement without dewatering the pumping-well grid cell. The maximum draw down observed at the pumping well after 365 days was 3.2 feet indicating that the aquifer was not highly stressed at this pumping rate. These results are consistent with OU-2 aquifer testing that resulted in approximately seven feet of draw down after five days of continuous pumping at 1.6 gpm.

## SUMMARY OF FINDINGS

Based on groundwater flow simulation results neither the Rocky Flats Alluvium nor the hillslope colluvium materials within OU-2 are capable of producing sufficient water to support a four-member household consuming 240 gallons per day. Using a 2.7 hour daily pumping period and a rate of 1.5 gpm, both the alluvium and the colluvium wells would be pumped dry within one day (table 5). In contrast, a well within the Arapahoe sandstone beneath OU-2 would appear to provide a reliable water resource at the required rates given above. The well grid-point in this simulation experienced only minimal drawdown after one year of daily-pumping cycles.

Table 5

Summary of simulation results

| FORMATION | WATER PRODUCTION DAYS |
|---|---|
| Rocky Flats Alluvium | <1 |
| Hillslope Colluvium | <1 |
| Arapahoe Sandstone | >365 |

To investigate the water resource potential for the OU-2 Arapahoe sandstone unit the total water available from this unit was computed (table 6). The average spatial dimensions of the sandstone unit were taken from isopach maps constructed from well and borehole information. The average saturated thickness is an assumed value derived from observational water level data and sandstone thickness information. The specific yield is assumed equal to the effective porosity as used above.

Assuming an annual water requirement of 2,920 cubic feet (equivalent to 60 gal/day • 365 days) there appears to be sufficient water volume in the sand to support ten four-person families for approximately 54 years (6,300,000 cu ft / (2,920 cu ft/person/year • 40 persons) = 53.9 years). This assumes complete desaturation of the aquifer (which is virtually impossible) and does not account for any external recharge to the aquifer.

Table 6

Arapahoe Sandstone Water Resource Evaluation

| DESCRIPTION | VALUE | UNITS |
|---|---|---|
| Length of sand | 4,200 | ft |
| Width of sand | 500 | ft |
| Sat. thickness of sand | 25 | ft |
| Total saturated sand vol | 52,500,000 | cu ft |
| Specific yield | 0.12 | |
| Total water volume | 6,300,000 | cu ft |
| | | |
| Daily water need | 60 | gal/person/day |
| Daily water need | 8 | cu ft/person/day |
| Annual water need | 2,920 | cu ft/person/year |
| | | |
| Available water | 2,158 | person/years |

## References

Fetter, C.W. Jr., 1980, Applied Hydrogeology, Merrill Publishing Company, Columbus, 488 p

McDonald, Michael G. and Harbaugh, Arlen W., 1988, Techniques of Water-Resources Investigations of the United States Geological Survey, Book 6, Chapter A1, A Modular Three-dimensional Finite-difference Groundwater Flow Model.

## TABLE D-3
## (Concluded)

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean[1] | Consider Further? |
| Strontium | 397 | 231 | 447 | 115 | No | Kruskal | 18 72 | <0 01 | Y | N | Y |
| Thallium | 4 | 2 | 4 | 2 | No | Kruskal | 0.55 | 0 46 | N | Y | N |
| Tin | 54 | 41 | 79 | 38 | No | Kruskal | 11 69 | <0 01 | Y | N | Y |
| Vanadium | 15 | 10 | 7 | 6 | No | Kruskal | 13 05 | <0 01 | Y | Y | N |
| Zinc | 13 | 17 | 11 | 11 | No | Kruskal | 4.23 | 0 04 | Y | Y | N |

[1] If the background mean is equal to or higher than OU-2 mean, a statistically significant difference ($P<0.05$) is not applicable

**TABLE D 3**
**ROCKY FLATS PLANT OU 2**
**ANOVA COMPARISON**
**DISSOLVED METALS IN GROUNDWATER, µg/L**
**NO 1 SANDSTONE**

| | Backgro nd | | OU 2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist | Test | Res lt (Ch -Square) | P – | Significantly Different? | Bknd Mean =/> OU2 Mean[1] | Consider Further |
| Al m n m | 111 | 468 | 59 | 51 | No | Kruskal | 0 83 | 0 36 | N | Y | N |
| Antimo y | 21 | 11 | 25 | 9 | No | Kruskal | 3 28 | 0 07 | N | N | N |
| Arsenic | 4 | 2 | 4 | 2 | No | Kruskal | 2 36 | 0 12 | N | Y | N |
| Bari m | 86 | 33 | 167 | 52 | No | Kruskal | 78 28 | <0 01 | Y | N | Y |
| Beryll m | ? | 1 | 2 | 0 78 | No | Kruskal | 1 31 | 0 25 | N | Y | N |
| Cadmi m | ? | 1 | 3 | 10 | No | Kruskal | 0 02 | 0.88 | N | N | N |
| Ces m | 386 | 237 | 363 | 181 | No | Kruskal | 0 11 | 0 75 | N | Y | N |
| Chrom m | 6 | 3 | 5 | 3 | No | Kruskal | 2 17 | 0 14 | N | Y | N |
| Cobalt | 19 | 10 | 21 | 9 | No | Kruskal | 1 03 | 0 31 | N | N | N |
| Copper | 13 | 21 | 9 | 5 | No | Kruskal | 1 74 | 0 19 | N | Y | N |
| Lead | 3 | 4 | 1 | 0.34 | No | Kruskal | 10 11 | <001 | Y | Y | N |
| L thi m | 38 | 45 | 13 | 14 | No | Kruskal | 32 22 | <0 01 | Y | Y | N |
| Manganese | 22 | 67 | 104 | 213 | No | Kruskal | 4 76 | 0 03 | Y | N | Y |
| Mercury | 0 12 | 0 17 | 0 09 | 0 04 | No | Kruskal | 2.51 | 0 11 | N | Y | N |
| Molybden m | 41 | 42 | 53 | 47 | No | Kruskal | 0 18 | 0 67 | N | N | N |
| Nickel | 15 | 8 | 15 | 7 | No | Kruskal | 0 07 | 0 80 | N | Y | N |
| Selen m | 6 | 12 | 2 | 1 | No | Kruskal | 4 74 | 0 03 | Y | Y | N |
| S lve | 6 | 3 | 4 | 2 | No | Kruskal | 3 15 | 0 08 | N | Y | N |

# TABLE D-2
# ROCKY FLATS PLANT OU-2
# 95% UTL COMPARISON
# DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L
# NO. 1 SANDSTONE

| | OU-2 Detected | | | Bknd | Bknd 95% | % OU-2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF | Max | UTL (1) | > 95% UTL |
| Americium-241 | 0 005 | 0 04 | 4/4 | - | NE | * |
| Cesium-137 | 0 6 | 0 5 | 2/4 | - | NE | * |
| Plutonium-239/240 | 0 006 | 0 006 | 4 4 | - | NE | * |
| Radium-226 | 0 3 | 1 0 | 19/19 | 2 9 | 3 86 | 0 |
| Strontium-89/90 | 0 009 | 1 6 | 87/95 | 1 3 | 0 9 | 6 3 |
| Tritium | 6 7 | 736 | 73/73 | 413 | 357 | 11 |
| Uranium-233/234 | 0 67 | 12 | 101/101 | 16 | 12 00 | 1 |
| Uranium-235 | 0 02 | 0 43 | 75/81 | 0 4 | 0 33 | 2 |
| Uranium-238 | 0 4 | 9 4 | 97/97 | 10 | 7 7 | 1 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992

DF = Detection frequency (no detects/no samples)
NE = not evaluated Data insufficient to calculate 95% UTL
* Comparison cannot be made

# TABLE D-4
## ROCKY FLATS PLANT OU-2
## ANOVA COMPARISON
## DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L
## NO. 1 SANDSTONE

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | BKG Mean >OU2 Mean[1] | Consider Further? |
| Americium 241 | --[2] | -- | 0 02 | 0 02 | No | Kruskal | 0 50 | 0 48 | N | -- | N |
| Cesium 137 | - | -- | 0 28 | 0 19 | No | Kruskal | -- | -- | -- | - | Y |
| Plutonium 239, 240 | -- | -- | <0 01 | <0 01 | No | Kruskal | -- | -- | - | - | Y |
| Radium 226 | 0 71 | 1 | 0 58 | 0 16 | No | Kruskal | 5 76 | 0 02 | Y | Y | N |
| Strontium 89,90 | 0 34 | 0 26 | 0 38 | 0 30 | No | Kruskal | 0 17 | 0 68 | N | N | N |
| Tritium | 130 | 104 | 202 | 150 | No | Kruskal | 7 09 | <0 01 | Y | N | Y |
| Uranium 233, 234 | 3 | 4 | 3 | 2 | No | Kruskal | 4 03 | 0 04 | Y | Y | N |
| Uranium 235 | 0 13 | 0 09 | 0 12 | 0 08 | No | Kruskal | 0 12 | 0 73 | N | Y | N |
| Uranium 238 | 2 | 3 | 2 | 1 | No | Kruskal | 8 31 | <0 01 | Y | Y | N |
| Total Radioactive Cesium | | - | 0 60 | 0 52 | - | - | - | | - | | Y |

[1] If the background mean is higher than OU-2 data mean a statistically significant difference (P<0 05) is not applicable
[2] One background data point

-- No data

# DISSOLVED METALS AND RADIONUCLIDES IN THE NO 1 SANDSTONE BACKGROUND COMPARISON

**TABLE D-1**
**ROCKY FLATS PLANT OU-2**
**95% UTL COMPARISON**
**DISSOLVED METALS IN GROUNDWATER, µg/L**
**NO. 1 SANDSTONE**

| | OU-2 Detected | | | Bknd | Background | % of OU-2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF % | Max | 95% UTL(1) | > 95% UTL(2) |
| Aluminum | 8 6 | 367 | 85 | 3,780 | 1,050 | 0 |
| Antimony | 9 | 56 | 15 | 36 | 44 | 2 |
| Arsenic | 1 | 1 | 6 | 15 | 8 | 0 |
| Barium | 82 | 352 | 100 | 182 | 152 | 59 |
| Beryllium | 1 | 3 | 5 | 3 5 | 4 | 0 |
| Cadmium | 1 | 98 | 13 | 7 | 4 | 2 |
| Cesium | 30 | 100 | 19 | 1,250 | 870 | 0 |
| Chromium | 3 | 23 | 19 | 16 | 11 | 5 |
| Cobalt | 3 | 3 | 1 | 25 | 40 | 0 |
| Copper | 2 | 9 | 19 | 175 | 55 | 0 |
| Lead | 1 | 2 | 5 | 22 | 10 | 0 |
| Lithium | 2 | 38 | 79 | 249 | 129 | 0 |
| Manganese | 1 | 1,240 | 68 | 440 | 158 | 20 |
| Mercury | 0 21 | 0 25 | 2 | 1 2 | 0 5 | 0 |
| Molybdenum | 3 | 16 | 36 | 114 | 125 | 0 |
| Nickel | 2 | 23 | 22 | 20 | 31 | 0 |
| Selenium | 1 | 10 | 48 | 76 | 31 | 0 |
| Silver | 2 | 4 | 7 | 12 5 | 12 | 0 |
| Strontium | 253 | 744 | 98 | 1,910 | 1,040 | 0 |
| Thallium | 1 | 2 | 6 | 5 | 8 | 0 |
| Tin | 14 | 34 | 7 | 100 | 137 | 0 |
| Vanadium | 3 | 10 | 76 | 25 | 35 | 0 |
| Zinc | 2 | 56 | 69 | 120 | 47 | 4 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant EG&G 1992
(2) UTL comparison is performed using one-half the detection limit for results reported as non-detect Therefore, the maximum detected value in OU-2 can be below the 95% UTL of background even through the UTL comparison shows that a certain percentage of OU-2 data exceeds the 95% UTL of background

DF = Detection frequency

**TABLE D-2**
**ROCKY FLATS PLANT OU-2**
**95% UTL COMPARISON**
**DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L**
**NO. 1 SANDSTONE**

| | OU-2 Detected | | | Bknd | Bknd 95% | % OU-2 data |
|---|---|---|---|---|---|---|
| Analyte | Min | Max | DF | Max | UTL (1) | > 95% UTL |
| Americium-241 | 0 005 | 0 04 | 4/4 | - | NE | * |
| Cesium-137 | 0 6 | 0 5 | 2/4 | - | NE | * |
| Plutonium-239/240 | 0 006 | 0 006 | 4 4 | - | NE | * |
| Radium-226 | 0 3 | 1 0 | 19/19 | 2 9 | 3 86 | 0 |
| Strontium-89/90 | 0 009 | 1 6 | 87/95 | 1 3 | 0 9 | 6 3 |
| Tritium | 6 7 | 736 | 73/73 | 413 | 357 | 11 |
| Uranium-233/234 | 0 67 | 12 | 101/101 | 16 | 12 00 | 1 |
| Uranium-235 | 0 02 | 0 43 | 75/81 | 0 4 | 0 33 | 2 |
| Uranium-238 | 0 4 | 9 4 | 97/97 | 10 | 7 7 | 1 |

(1) Background Geochemical Characterization Report, Rocky Flats Plant, EG&G 1992

DF = Detection frequency (no detects/no samples)
NE = not evaluated Data insufficient to calculate 95% UTL
* Comparison cannot be made

# TABLE D-3
# ROCKY FLATS PLANT OU-2
# ANOVA COMPARISON
# DISSOLVED METALS IN GROUNDWATER, µg/L
# NO. 1 SANDSTONE

| Analyte | Background Mean | Background SD | OU-2 Data Mean | OU-2 Data SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean[1] | Consider Further? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum | 111 | 468 | 59 | 51 | No | Kruskal | 0.83 | 0.36 | N | Y | N |
| Antimony | 21 | 11 | 25 | 9 | No | Kruskal | 3 28 | 0 07 | N | N | N |
| Arsenic | 4 | 2 | 4 | 2 | No | Kruskal | 2 36 | 0 12 | N | Y | N |
| Barium | 86 | 33 | 167 | 52 | No | Kruskal | 78 28 | <0 01 | Y | N | Y |
| Beryllium | 2 | 1 | 2 | 0 78 | No | Kruskal | 1 31 | 0 25 | N | Y | N |
| Cadmium | 2 | 1 | 3 | 10 | No | Kruskal | 0 02 | 0 88 | N | N | N |
| Cesium | 386 | 237 | 363 | 181 | No | Kruskal | 0 11 | 0 75 | N | Y | N |
| Chromium | 6 | 3 | 5 | 3 | No | Kruskal | 2 17 | 0 14 | N | Y | N |
| Cobalt | 19 | 10 | 21 | 9 | No | Kruskal | 1 03 | 0 31 | N | N | N |
| Copper | 13 | 21 | 9 | 5 | No | Kruskal | 1 74 | 0 19 | N | Y | N |
| Lead | 3 | 4 | 1 | 0.34 | No | Kruskal | 10 11 | <001 | Y | Y | N |
| Lithium | 38 | 45 | 13 | 14 | No | Kruskal | 32 22 | <0 01 | Y | Y | N |
| Manganese | 22 | 67 | 104 | 213 | No | Kruskal | 4 76 | 0 03 | Y | N | Y |
| Mercury | 0 12 | 0 17 | 0 09 | 0 04 | No | Kruskal | 2.51 | 0 11 | N | Y | N |
| Molybdenum | 41 | 42 | 53 | 47 | No | Kruskal | 0 18 | 0 67 | N | N | N |
| Nickel | 15 | 8 | 15 | 7 | No | Kruskal | 0 07 | 0 80 | N | Y | N |
| Selenium | 6 | 12 | 2 | 1 | No | Kruskal | 4 74 | 0 03 | Y | Y | N |
| Silver | 6 | 3 | 4 | 2 | No | Kruskal | 3 15 | 0 08 | N | Y | N |

## TABLE D-3
## (Concluded)

| Analyte | Background Mean | Background SD | OU-2 Data Mean | OU-2 Data SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | Bknd Mean =/> OU2 Mean[1] | Consider Further? |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Strontium | 397 | 231 | 447 | 115 | No | Kruskal | 18 72 | <0 01 | Y | N | Y |
| Thallium | 4 | 2 | 4 | 2 | No | Kruskal | 0.55 | 0 46 | N | Y | N |
| Tin | 54 | 41 | 79 | 38 | No | Kruskal | 11 69 | <0 01 | Y | N | Y |
| Vanadium | 15 | 10 | 7 | 6 | No | Kruskal | 13 05 | <0 01 | Y | Y | N |
| Zinc | 13 | 17 | 11 | 11 | No | Kruskal | 4 23 | 0 04 | Y | Y | N |

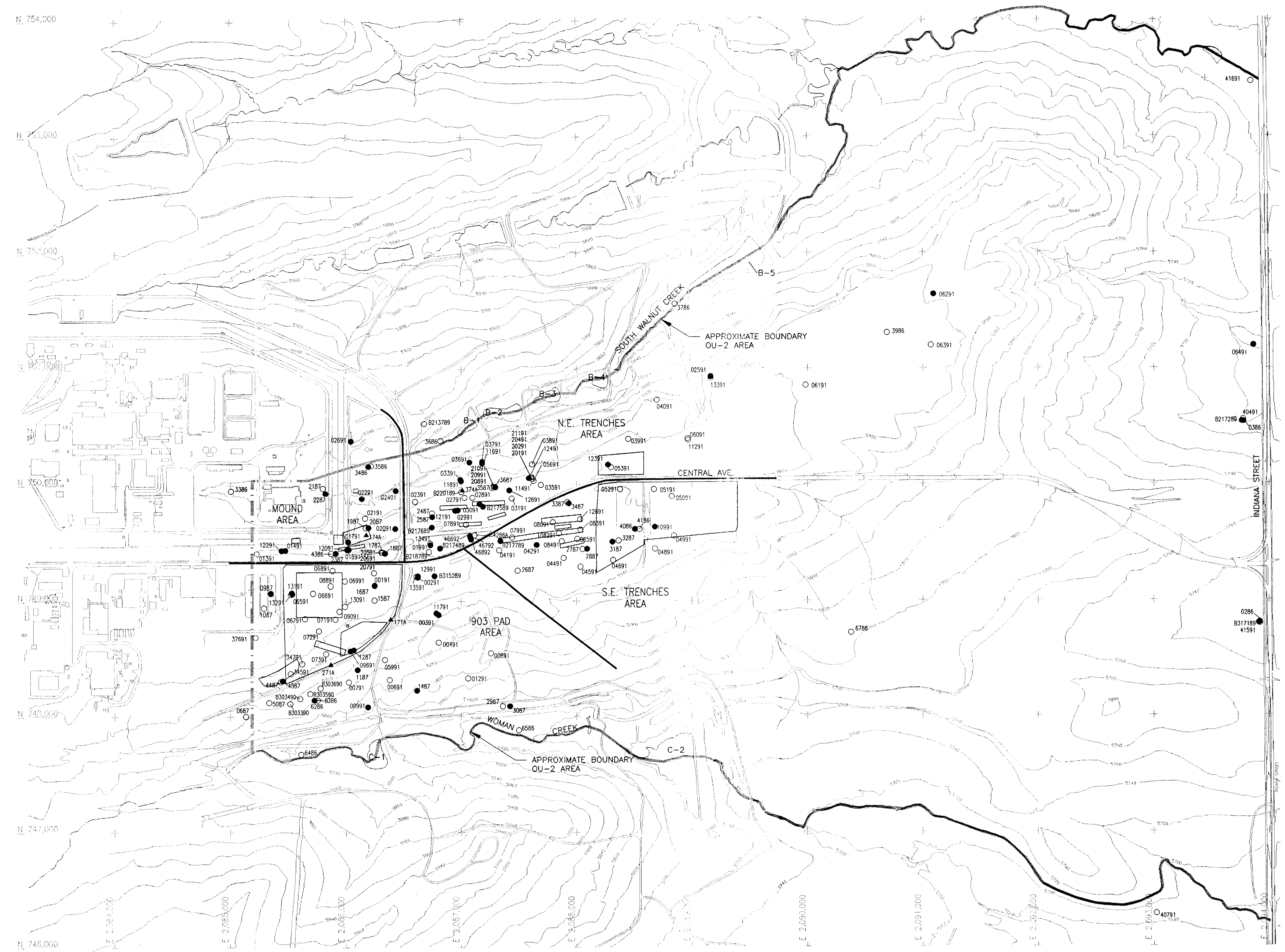
[1] If the background mean is equal to or higher than OU-2 mean, a statistically significant difference (P<0 05) is not applicable

**TABLE D-4**
**ROCKY FLATS PLANT OU-2**
**ANOVA COMPARISON**
**DISSOLVED RADIONUCLIDES IN GROUNDWATER, pCi/L**
**NO. 1 SANDSTONE**

| | Background | | OU-2 Data | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Analyte | Mean | SD | Mean | SD | Norm Dist? | Test | Result (Chi-Square) | P = | Significantly Different? | BKG Mean >OU2 Mean[1] | Consider Further? |
| Americium 241 | --[2] | -- | 0 02 | 0 02 | No | Kruskal | 0 50 | 0 48 | N | -- | N |
| Cesium 137 | - | -- | 0 28 | 0 19 | No | Kruskal | -- | - | -- | - | Y |
| Plutonium 239, 240 | -- | - | <0 01 | <0 01 | No | Kruskal | - | - | -- | - | Y |
| Radium 226 | 0 71 | 1 | 0 58 | 0 16 | No | Kruskal | 5 76 | 0 02 | Y | Y | N |
| Strontium 89,90 | 0 34 | 0 26 | 0 38 | 0 30 | No | Kruskal | 0 17 | 0 68 | N | N | N |
| Tritium | 130 | 104 | 202 | 150 | No | Kruskal | 7 09 | <0 01 | Y | N | Y |
| Uranium 233, 234 | 3 | 4 | 3 | 2 | No | Kruskal | 4 03 | 0 04 | Y | Y | N |
| Uranium 235 | 0 13 | 0 09 | 0 12 | 0 08 | No | Kruskal | 0 12 | 0 73 | N | Y | N |
| Uranium 238 | 2 | 3 | 2 | 1 | No | Kruskal | 8 31 | <0 01 | Y | Y | N |
| Total Radioactive Cesium | - | - | 0 60 | 0 52 | - | - | - | | | | Y |

[1] If the background mean is higher than OU-2 data mean a statistically significant difference (P<0 05) is not applicable
[2] One background data point

-- No data




## EXPLANATION

| | |
|---|---|
| 3786 ○ | 1986-1990 ALLUVIAL MONITORING WELL |
| 3087 ● | 1986-1990 BEDROCK MONITORING WELL |
| 00191 ○ | 1991-1992 ALLUVIAL MONITORING WELL |
| 12691 ● | 1991-1992 BEDROCK MONITORING WELL |
| 20591 20691 20791 | 1991 TEST WELL CLUSTER |
| 4286A ○ | ABANDONED MONITORING WELL |
| 174A ▲ | 1971-1974 MONITORING WELL |
| | INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION |
| | APPROXIMATE BOUNDARY OF OU-2 STUDY AREA |

SCALE : 1 INCH = 500 FEET

1000' 0 1000'

CONTOUR INTERVAL = 20'

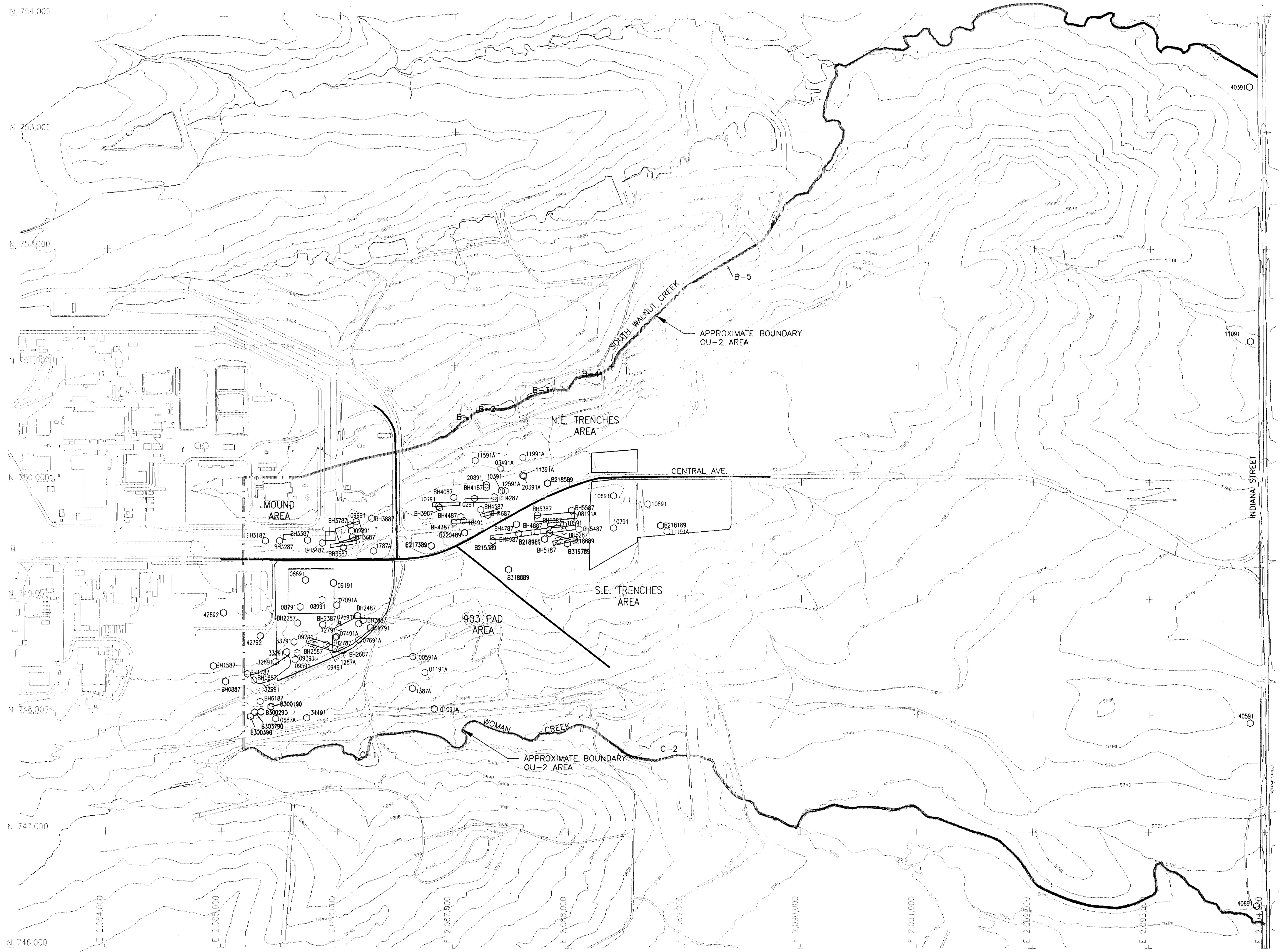
U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

OPERABLE UNIT NO.2
CHEMICALS OF CONCERN
TECHNICAL MEMORANDUM NO.9

# OU-2 MONITORING WELL LOCATIONS
(HISTORICAL, PHASE II, AND OTHER INVESTIGATIONS)

FIGURE 3-1 AUGUST 1993

OU2TM931 1=500




## EXPLANATION

BH1587 ○ 1987 BOREHOLE LOCATION

B319789 ○ 1989–1990 BOREHOLE LOCATION

09491 ○ 1991–1992 BOREHOLE LOCATION

01091A ○ ABANDONED MONITORING WELL INSTALLATION ATTEMPT

INDIVIDUAL HAZARDOUS SUBSTANCE SITE LOCATION

APPROXIMATE BOUNDARY OF OU-2 STUDY AREA

-N-

SCALE : 1 INCH = 500 FEET

1000' 0 1000'

CONTOUR INTERVAL = 20'

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

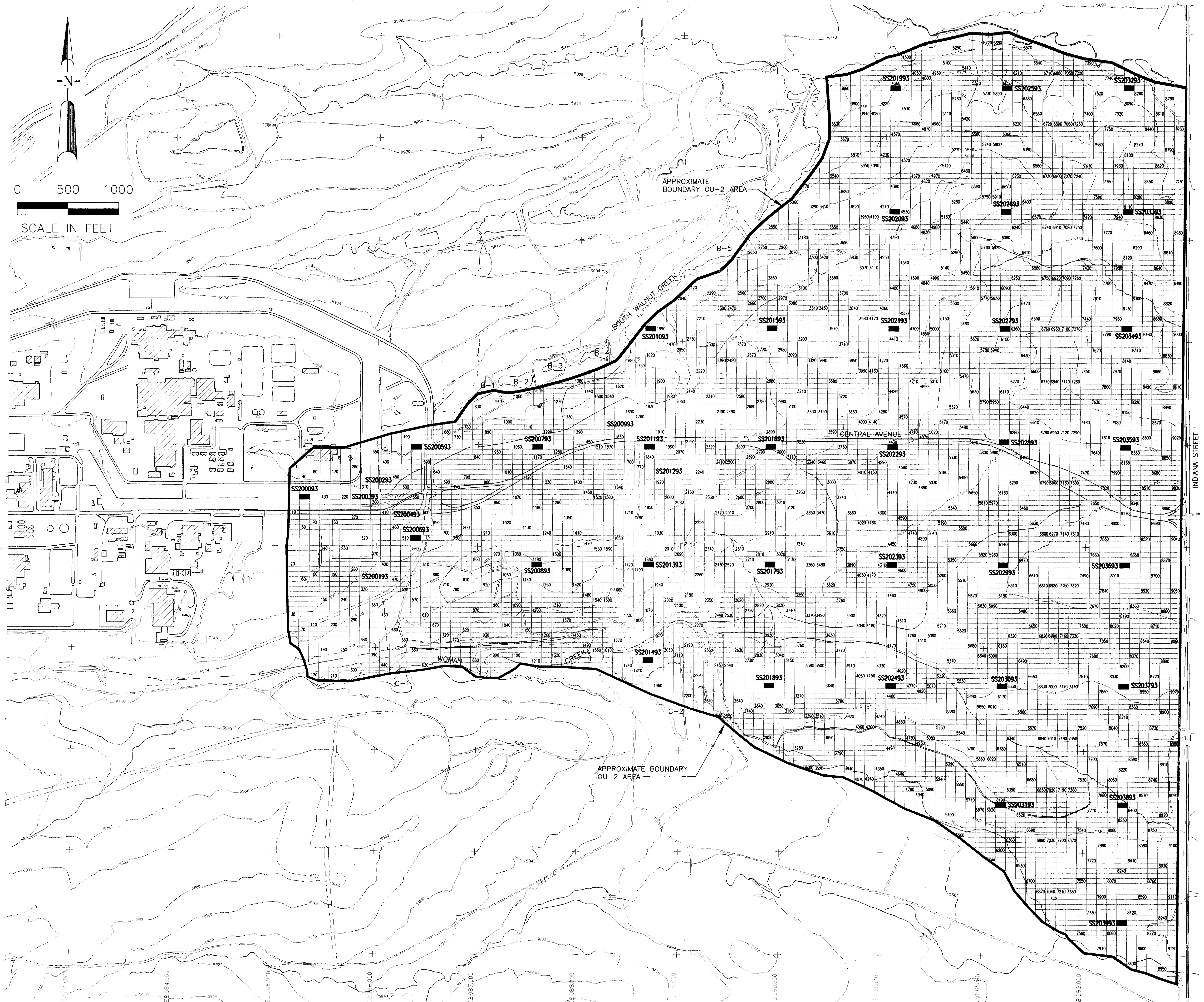
OPERABLE UNIT NO.2
CHEMICALS OF CONCERN
TECHNICAL MEMORANDUM NO.9

# OU–2 BOREHOLE LOCATIONS

(HISTORICAL, PHASE II, AND OTHER INVESTIGATIONS)

FIGURE 4–1 AUGUST 1993

OU2TM941 1=500




## EXPLANATION

| | |
|---|---|
| 8610 | 50'x100' PLOT |
| SS200193 | BIASED SURFICIAL SOIL SAMPLING PLOT LOCATION |
| SS200093 | GRID-BASED SURFICIAL SOIL SAMPLING PLOT LOCATION |

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1993 SURFICIAL SOIL SAMPLING PLOT LOCATIONS

FIGURE 5-2 AUGUST 1993

OU2TM952 1=500